

NASA Contractor Report 191446

**Civil Tiltrotor Transport Point Design -
Model 940A**

C. Rogers, D. Reisdorfer

Bell Helicopter **TEXTRON**

A Subsidiary of Textron Inc.

Fort Worth, Texas 76101

**Contract NAS1-18796
April 1993**

NASA

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-0001

(NASA-CR-191446) CIVIL TILTROTOR
TRANSPORT POINT DESIGN: MODEL 940A
Final Report (Bell Helicopter Co.)
92 p

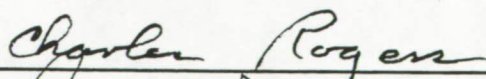
N93-32234

Unclas

G3/24 0177414

ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

Civil Tiltrotor Transport Point Design - Model 940A


Project Engineer
C. Rogers

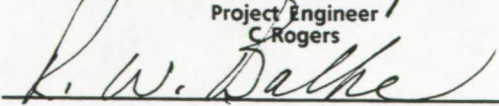

Manager Research and Technology Programs
R. Balke

TABLE OF CONTENTS

	<u>Page</u>
PREFACE	1
SUMMARY	1
INTRODUCTION	1
Parametric Configuration and Loads Definition	8
Configuration	8
Geometry	8
Lift - Propulsion System	24
Landing Gear Placement, Tiltrotor	24
Loads	26
Load factors and accelerations	29
Shear and moment diagrams	29
Dynamics stiffness criteria	29
Materials and allowables	65
Rods	71
Skins	71
Allowables	71
CIVIL TILTROTOR WING BOX	75
CIVIL TILTROTOR CENTER FUSELAGE	75
Wing Fuselage Intersection	76
Main Landing Gear Bay	76
CONCLUSIONS	83
APPENDIX A	A-1

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Forty passenger civil tiltrotor - Model 940A	2
2	Three views - Model 940A	3
3	View of wing concept	4
4	View of fuselage concept	5
5	View of fuselage upper longeron which provides for wing-fuselage attachment	6
6	Section through upper longeron at front spar attachment fitting	7
7a	Flowchart for tiltrotor preliminary structural sizing	9
7b	GARP synthesis flowchart	10
8	Tiltrotor sign convention	24
9	Sketch of nacelle and related geometry	27
10	Sketch of landing gear placement parameters	28
11	Fuselage Vertical Shear & Moment Diagrams - 2-G	47
12	Wing Shear - 2-G	47
13	Wing Moment - 2-G	48
14	Wing Torque - 2-G	48
15	Fuselage Vertical Shear & Moment Diagrams - 4-G	55
16	Wing Shear - 4-G	55
17	Wing Moment - 4-G	56
18	Wing Torque - 4-G	56
19	Fuselage Vertical Shear & Moment - 110 kt - 75° Tilt	62
20	Fuselage Horizontal Shear & Moment - 110 kt - 75° Tilt	62
21	Wing Shear - 110 kt - 75° Tilt	63
22	Wing Moment - 110 kt - 75° Tilt	63
23	Wing Torque - 110 kt - 75° Tilt	64
24	Unit Wing Skin and Spar Inertias	67
25	Unit Corner Cap Inertias	68
26	Unit Stringer Inertias	69
27	Modulus vs A/L for IM7/epoxy	72
28	Strength vs A/L for IM7/epoxy	73
29	Wing Box Section	76
30	Wing Box Planform	77
31	Detail of Skin and Stringer	79
32	Fuselage section FS300	80
33	Fuselage Profile	81
A-1	Comparison of 23% and 21.9% airfoil geometry	A-3

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1 Configuration output from GARP	11
2 System weights and coordinates - cruise mode	12
3 System weights and coordinates - hover mode	18
4 Geometry for nacelle - cruise mode	25
5 Geometry for nacelle - hover mode	26
6 Geometry for landing gear ground contact points - helicopter mode	27
7 External Loads for Nine Flight Conditions	30
8 Translational and Angular Accelerations for Nine Flight Conditions	36
9 Input Data for Internal Loads - 2G jump take-off	42
10 Output Data for Internal Loads - 2G jump take-off	45
11 Input Data for Internal Loads - 289 kn, 4G symmetrical pull up	49
12 Output Data for Internal Loads - 289 kn, 4G symmetrical pull up	52
13 Input Data for Internal Loads - 110 kn - 75° Tilt	57
14 Output Data for Internal Loads - 110 kn - 75° Tilt	60
15 Dynamic Frequency Placement Guide for Tiltrotor Preliminary Design	64
16 Input Data for Initial Wing Stiffness Computations	66
17 Frequency and Mode Shape Comparisons - V-22 and Civil Tiltrotor	70
18 Typical Laminae Properties for G30-500/E7T1 Tape	74
19 Wing Element Sizing	78
20 Fuselage Element Sizing	82
A-1 Model 94A airfoil coordinates	A-2

PREFACE

The objective of this effort is to produce a vehicle layout for the civil tiltrotor wing and center fuselage in sufficient detail to obtain aerodynamic and inertia loads for determining member sizing.

This report addresses the parametric configuration and loads definition for a 40 passenger civil tilt rotor transport. A preliminary (point) design is developed for the tiltrotor wing box and center fuselage.

This summary report provides all design details used in the pre-design; provides adequate detail to allow a preliminary design finite element model to be developed; and, contains guidelines for dynamic constraints.

This work was performed as part of NASA Contract NAS1-18796, Advanced Materials and Structural Concepts, administered by Mr. Don Baker of the Vehicle Structures Directorate Army Research Laboratory, NASA Langley Research Center. The Project Engineer for the contractor, Bell Helicopter Textron Incorporated was Mr. Charles W. Rogers.

SUMMARY

The purpose of this effort, that of producing a point design vehicle layout for the Civil Tiltrotor wing and center fuselage in sufficient detail to obtain aerodynamic and inertia loads for determining member sizing, has been accomplished. The point design designated the Model 940A is illustrated in Figure 1. Figure 2 contains the geometry in 3 views.

The lack of definitive requirements for maneuvers, load factors, and automatically limiting control devices, necessitated assumptions relative to these requirements and implementations. Other limitations are those normally related to a pre-design effort, and pertain to the limited amount of design detail available.

The parametric configuration and loads were developed for a 40 passenger civil tiltrotor vehicle. This report presents the configuration, system weights and coordinates, external loads, and resulting linear and angular accelerations. These data are used to obtain shear and moment information from which preliminary structural

strength requirements are derived. Additionally, structural dynamic frequency placement guidelines derived from XV-15 and V-22 designs are generated, from which stiffness requirements are derived.

Pre-design level analytical tools were utilized to develop the preliminary design of the Model 940A wing box sufficient to define its geometry, structural concept and initial composite laminate sizing; meeting stiffness and strength requirements. Figure 3 contains a partially assembled view of the wing box showing the lower skin, ribs and front and rear spars.

Pre-design level analytical tools were utilized to complete the pre-design of the Model 940A center fuselage in sufficient detail to define the structural concept and obtain composite laminate sizing. Figure 4 shows the ring frame and stiffened skin concept selected for the fuselage.

Upper longerons are required in the vicinity of the wing and lower longerons are required near the main gear. These longerons are molded structures exterior to the skin as illustrated in Figure 5.

Figure 6 shows a cross section through the upper longeron at a wing attachment fitting. The major loads are introduced directly into the laminate without the aid of metal fittings.

The results of this effort provide: a vehicle layout for the Model 940A point design Civil Tiltrotor wing and center fuselage in sufficient detail to obtain aerodynamic and inertia loads for determining member sizing; geometry, weight and structural sizing suitable for future finite element modeling for structural optimization; and guidelines for tiltrotor dynamic design constraints.

INTRODUCTION

Prior Civil Tiltrotor Study Contracts

Bell Helicopter Textron Incorporated (BHTI) and Boeing Helicopters have jointly conducted configuration studies for a civil tiltrotor under a NASA Contract entitled "Civil Tiltrotor Missions and Applications: A Research Study." The results are published in NASA Contract Report 177451. Additionally, BHTI has conducted a

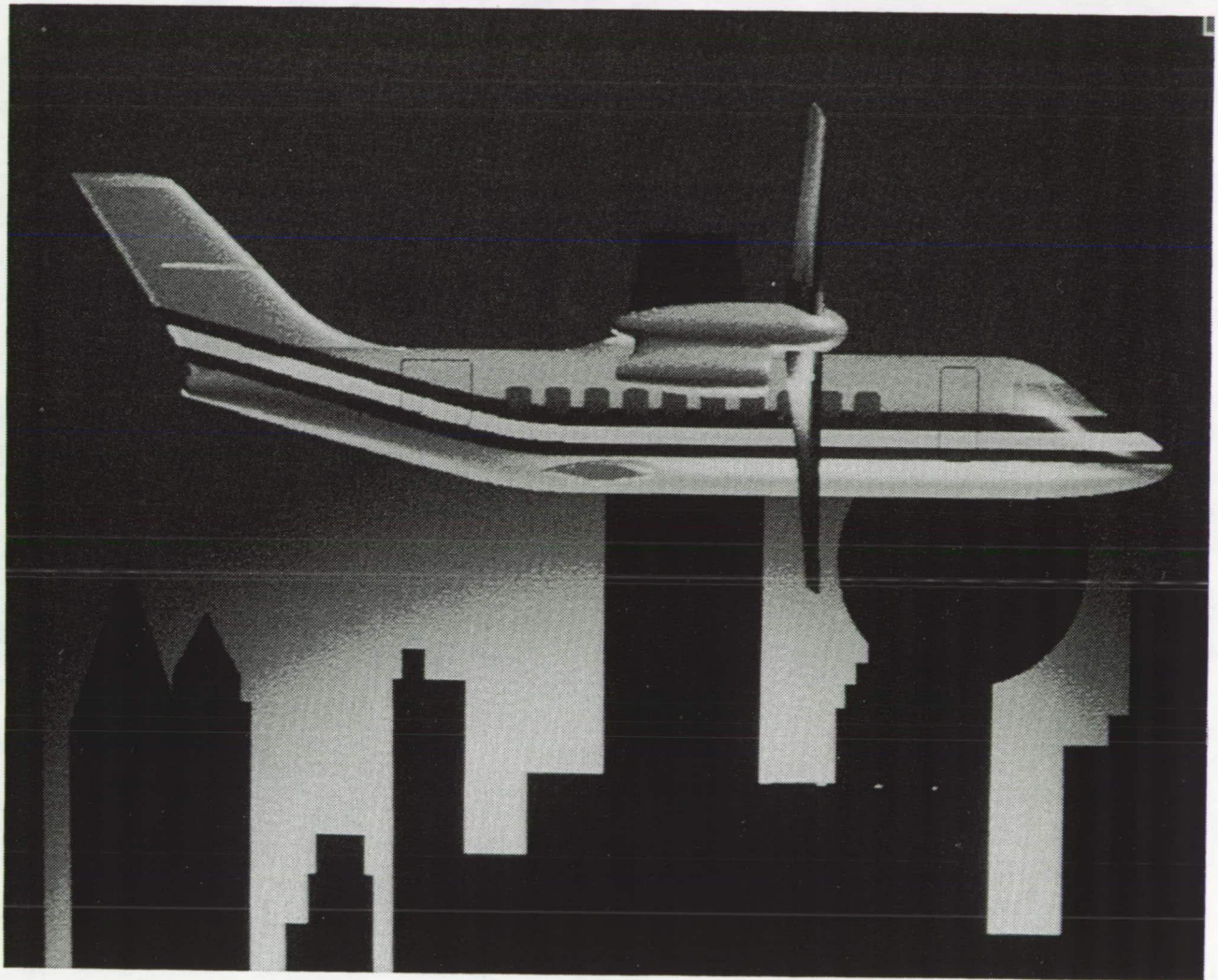
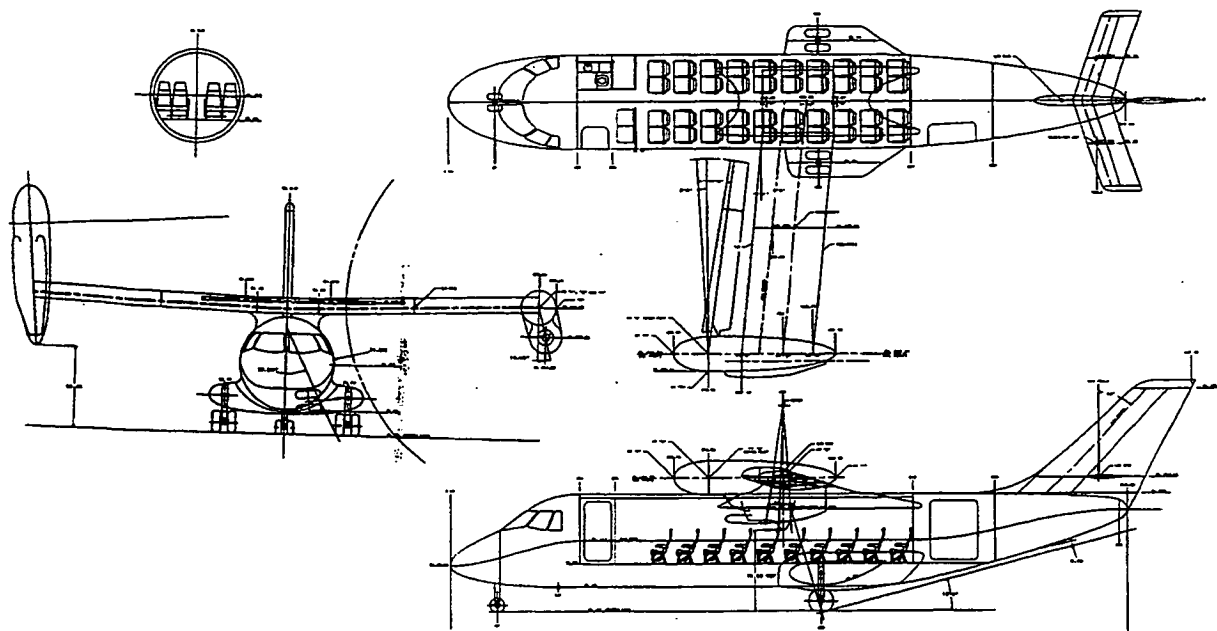


Figure 1. Forty passenger civil tiltrotor - Model 940A.



2-E561

Figure 2. Three view - Model 940A.

study of the "Technology Needs for High Speed Rotorcraft", Contract No. NAS2-13072, summarized in NASA Final Report 177592.

These prior studies of the potential for high speed vertical takeoff and landing (VTOL) vehicles for commercial passenger transport have confirmed the applicability of a tiltrotor operating at speeds up to 375 knots. These studies further indicate that a 40 passenger, 600 mile range vehicle would offer the best productivity, where productivity is expressed as the ratio of payload times block time over fuel plus vehicle dry weight.

Previous efforts on the same contract examined new structural and manufacturing concepts intended to significantly reduce the cost of composite structure of the commercial transport type. The results of this effort provided a broad range of attractive design, material form and manufacturing concepts which taken together could significantly reduce cost while maintaining or further reducing the structural weight fraction achieved through use of composite materials.

One of the new material forms and applications conceived by BHTI was directed at forming and constraining the fibers to a specified straightness criteria in order to increase the compressive load-

ing allowable. The form utilized is that of a "rod". The rods are manufactured through a pultrusion process. The size of the rods are of diameters from 0.030 to 0.070 inches. The application concept is to embed the rods within a load carrying member at or near the structural element extremities where high compression (and tension) stresses and strains will occur. The major consideration in this application is the means of transferring loads into and out of the rods.

Fabrication and testing of coupons for transferring of loads into and out of the rods is currently in progress. This task considers methods by which load can be introduced at the ends of layers of rods which must be terminated due to an assembly splice or some other requirement.

The objective of this report is to produce a Civil Tiltrotor vehicle (CTR) layout for a point design, designated the Model 940A. In particular to define the tiltrotor wing and center fuselage in sufficient detail to obtain aerodynamic and inertial loads and determining an initial member sizing.

This report addresses the parametric configuration and loads definition for a 40 passenger civil tiltrotor vehicle. A preliminary (point) design is developed for the tiltrotor wing box and center fuselage.

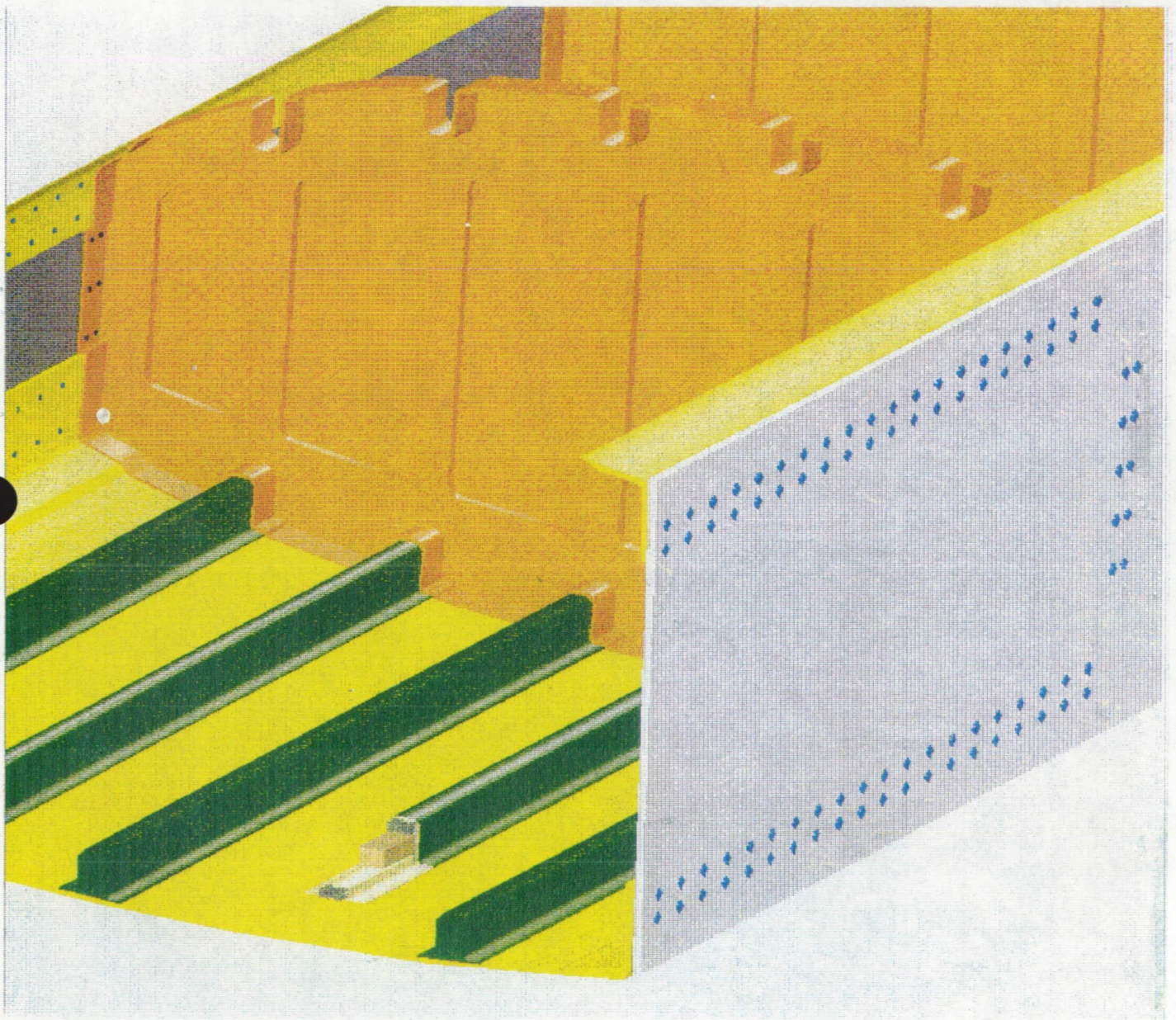


Figure 3. View of wing concept.

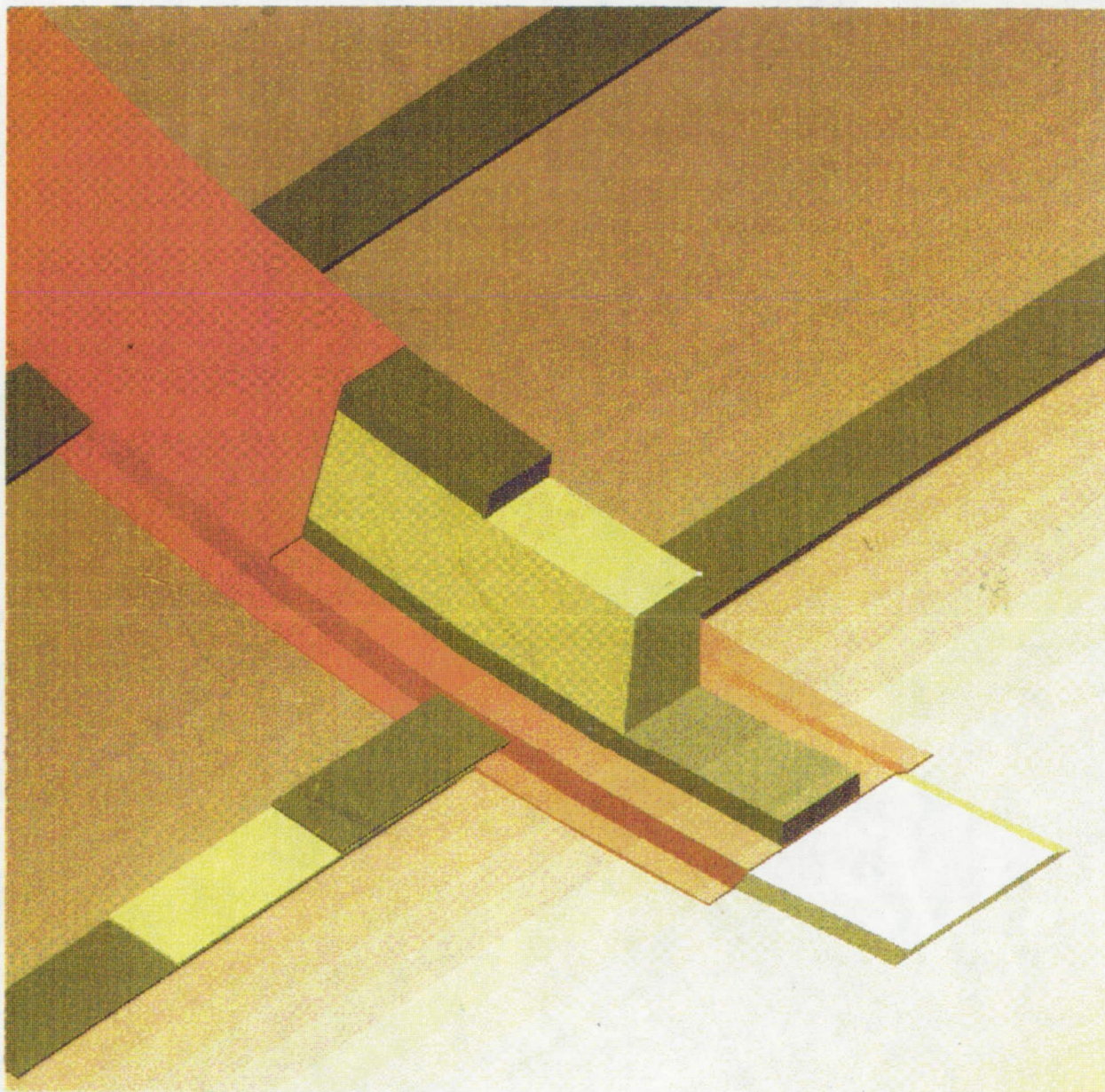


Figure 4. View of fuselage concept.

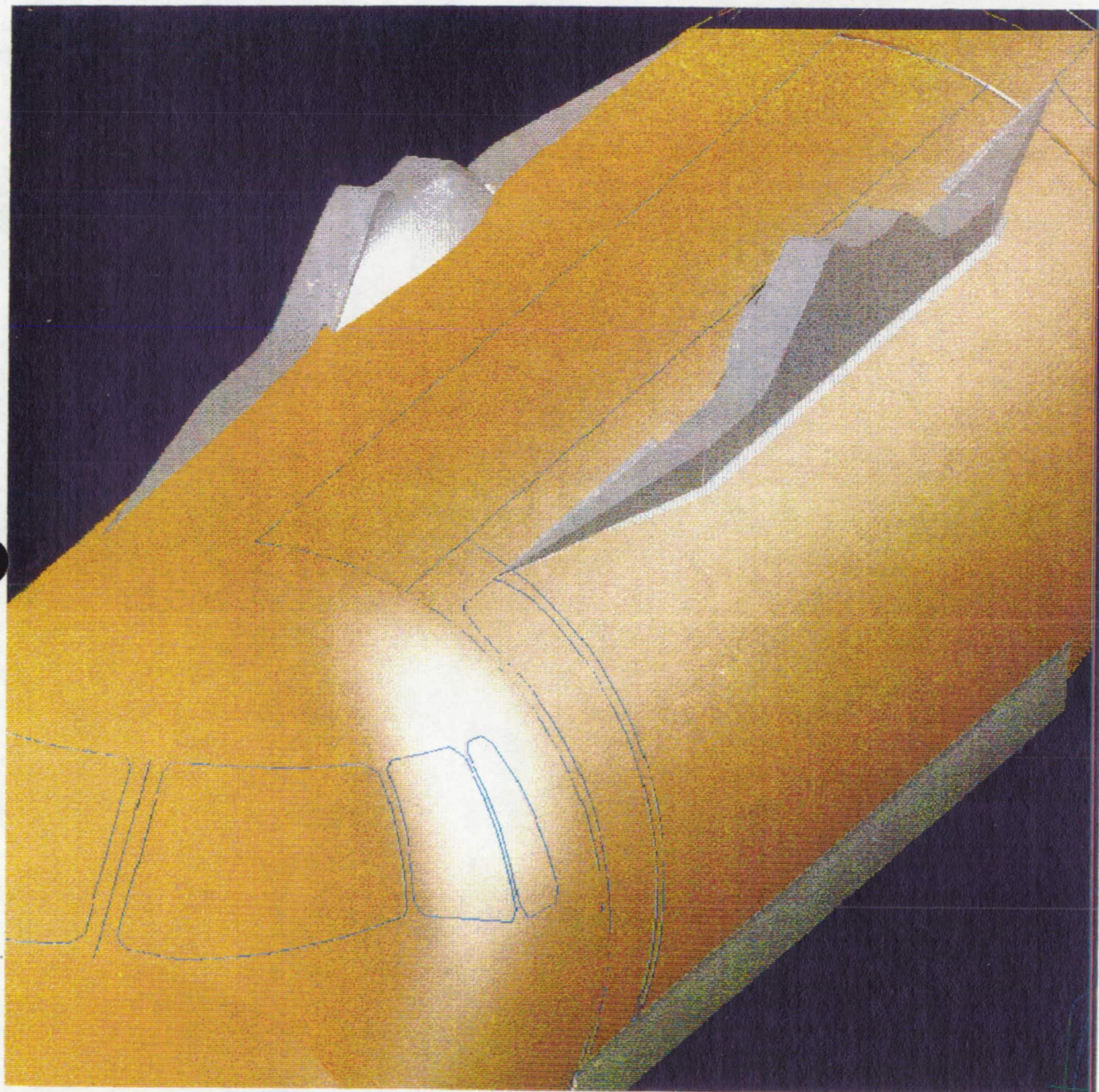


Figure 5. View of fuselage upper longeron which provides for wing-fuselage attachment.

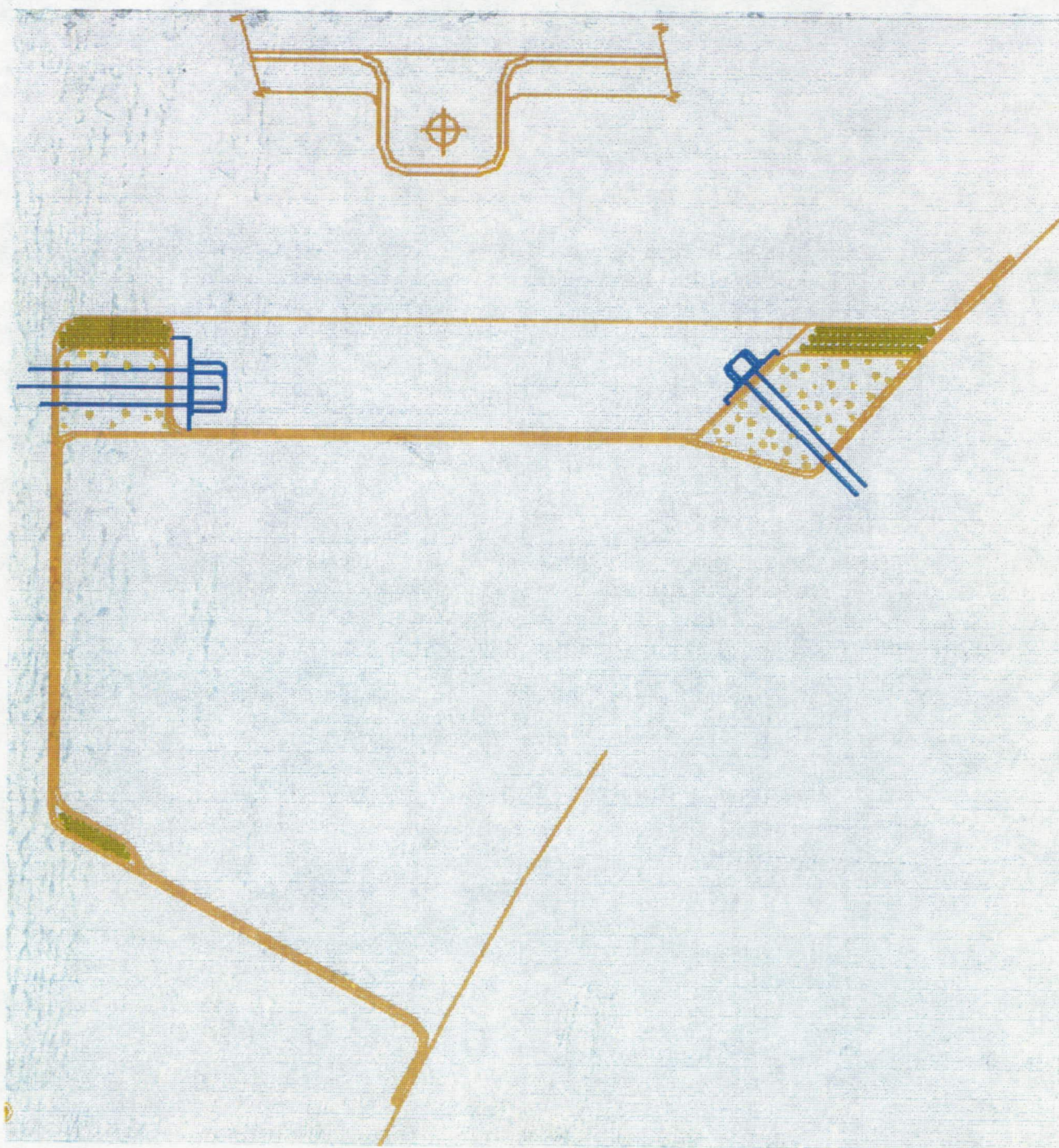


Figure 6. Section through upper longeron at front spar attachment fitting.

The major assumptions and limitations of the subject effort relate to the lack of definitive critical load maneuvers required for certification of a Civil Tiltrotor vehicle. This necessitated assumptions of critical maneuvers and load factors, which surprisingly produced higher thrust conditions than that of for the military V-22 tiltrotor during a jump takeoff. Obviously, these assumptions will bear further inspection as the design of a CTR progresses.

The flow of work, described in Figure 7a, starts with a preliminary design, configuration development, routine entitled "Generalized Advanced Rotorcraft Program" (GARP) which develops a solution in terms of geometry and horsepower for a given performance objective. Structural advancements are accounted for by "technical factors" on the various controlling parameters. The output of this program includes XYZ coordinates for the various masses of the airframe, systems and payload. This information allows development of shear, moment, and torque diagrams for the wing and fuselage using external loads developed from the configuration geometry data. A parallel operation defines the required wing stiffness anticipated for dynamic stability using the mass and geometry data only. These data are sufficient for sizing the various elements of the structure preparatory to Finite Element Modeling.

PARAMETRIC CONFIGURATION AND LOADS DEFINITION

CONFIGURATION

A computer model developed under Bell independent research and development (IR&D) is used to synthesize the conceptual point-design aircraft designated Model 940A. The computer code uses parametric weight estimating expressions derived from the V-22 (GARP).

The process utilized in GARP follows the following steps:

- a trial design gross weight is selected; geometry and transmission and engine ratings are established to meet takeoff and cruise criteria;

- the mission profile fuel requirements are computed to attain the design range;

- weight empty is determined; and

- a takeoff gross weight is calculated.

The error between the trial and calculated weight is the basis for a new trial gross weight. When the error is reduced to an acceptable level, the aircraft size solution is achieved. This process is illustrated in Figure 7b.

Configuration studies prior to this program established a 40 passenger, 375 kn cruise, 600 mile range tiltrotor as having the best productivity given 1991 technology. The actual payload is 8,000 lb., assuming 200 lb. per passenger. The output of GARP in terms of configuration data is summarized in Table 1. Geometry and parametric configuration data such as wing T/C are input along with initial gross weight estimate. Certain variables are calculated based upon internal guidelines in the program.

Since a spread sheet format was used to present the mass of data generated in the computation of the shear and moment diagrams, many portions of the data may seem repetitive, such a case occurs on page 20. Buttock Line 305 corresponds to the starboard nacelle and rotor axis. Rotor transmission, engine and many systems are placed along this BL. These items are at different fuselage stations as can be seen on the same page.

System weight by category is summarized in Tables 2 and 3 for the cruise and hover modes.

The column in the tables designated "C" indicates the component: w = wing, f = fuselage, n = nacelle. The component weight is recorded in the weight statement. Also included at the end of this table are the external loads, lift, drag, and thrust as computed by GARP. The last page of Table 2 shows a force-balance check about the two center of gravity extremes as defined in Figure 9.

GEOMETRY

The 40-passenger Civil Tiltrotor vehicle size is the result of a mission optimization process using the PC-based tiltrotor sizing program. Generation of an aircraft three-view with greater definition than is possible from the mass coordinates given in the preliminary loads spreadsheet has led to the need to breakout the geometric coordi-

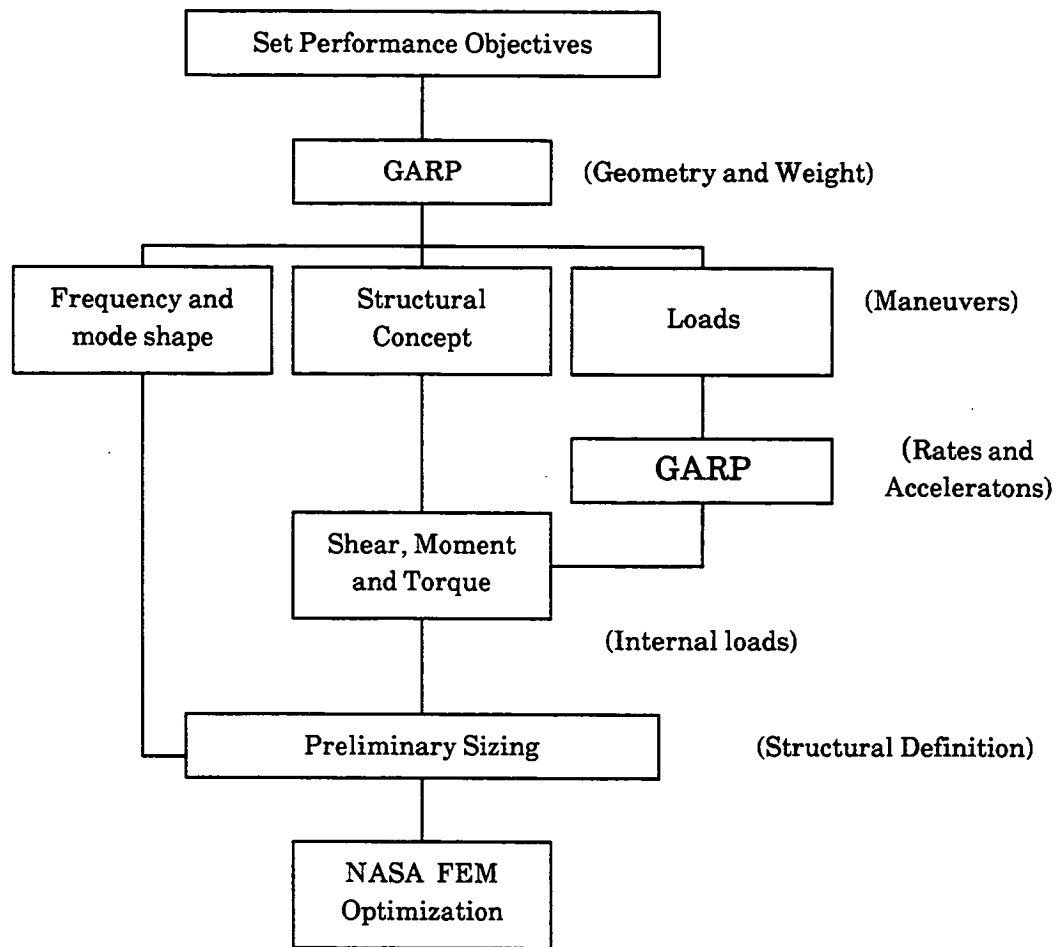


Figure 7a. Flowchart for tiltrotor preliminary structural sizing.

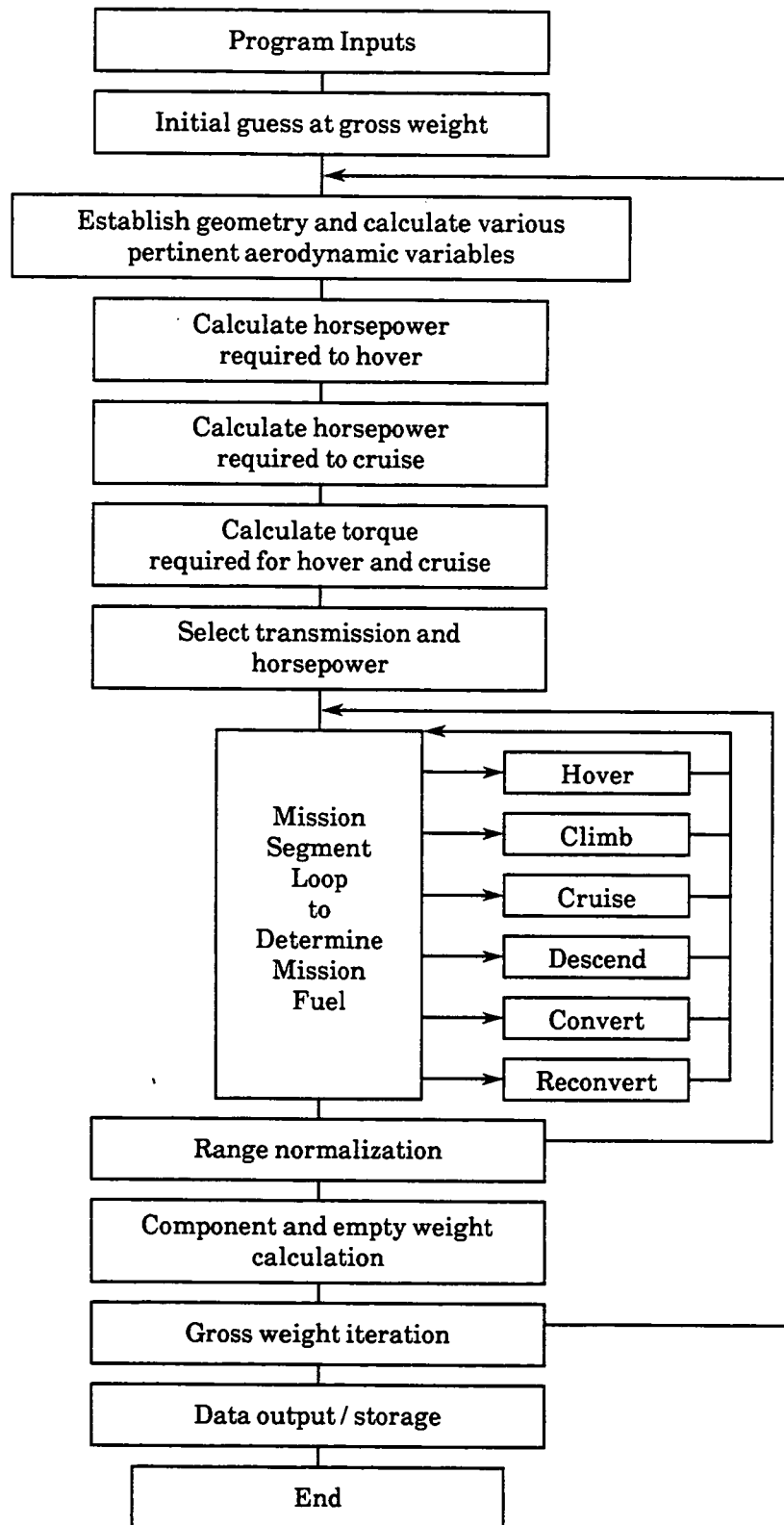


Figure 7b. GARP synthesis flowchart.

Table 1. Configuration output from GARP

INPUTS	FT OR RAD	INCHES			
Body Length	68.33	819.96			
Body Width	9.5	114			
Wing Span	50.88	610.56			
Wing Chord	7.14	85.68			
Wing Sweep Radians	-0.104719		40 Passenger Civil Tiltrotor		
Wing Dihedral Radians	0.049065		Current Technology		
Wing T/C	0.216		Cruise Altitude = 15,000 ft		
Wing Dihed	0.0349065		Disk Loading = 17.9, Tip Speed Ratio = .768, Hover Tip Speed = 780		
VTail Span	10.71	128.52	Cruise Design Velocity = 372 KTAS, Range = 600 N.Mi.		
VTail Chord	8.93	107.16	Productivity Index = 80.24		
VT T/C	0.09				
VT Sweep	0.7504915		8/13/1991 12:44:00		
HTail Span	17.19	206.28			
HTail Chord	3.91	46.92			
HT T/C	0.09				
HTail Sweep	0.3316125				
VT Tail Arm	32.57	390.84			
Rotor Radius	19.69	236.28			
HP/Engine	7790.852				
Nacelle Angle	0		Nacelle Dihedra 0.069893		
CALC. VARIABLE	FEET	INCHES	CALC. VARIABLE	FEET	INCHES
Wing Cntr. .25C	34.044202	408.5	Conv. Axis (W.L.)	16.15896	193.9075
Wing MAC (F.S.)	32.714601	392.6	Wing Cntr. .25C	34.044202	408.5
VTail MAC (F.S.)	65.284601	783.4			
Conv. Axis (F.S.)	33.669800	404.0			
Hub Hover (W.L.)	23.525763	282.3			
Eng. Diameter	2.7075156	32.5			
Nacelle Length	14.001295	168.0			
Spinner Diam.	3.50482	42.1			
Lpylon	7.3668003	88.4			
Body Radius	4.75	57			
Wing Thickness	1.54224	18.5			

Table 2. System weights and coordinates - cruise mode.

COMPONENT	INDIVIDUAL WEIGHT	GROUP WEIGHT	LOCATION			MOMENT ABOUT 0,0,0			MOMENT ABOUT C.G.			
			BL	WL	FS	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	WL in.lbs	FS in.lbs	
Wing Group												
#1 Wing	454.9	2729.3	w	229	191	385	104150	86994	174947	104163	18986	-2825
#2 Wing	454.9		w	153	189	393	69433	85782	178576	69446	17775	804
#3 Wing	454.9		w	76	186	401	34717	84571	182205	34730	16563	4433
#4 Wing	454.9		w	-229	191	385	-104150	86994	174947	-104137	18986	-2825
#5 Wing	454.9		w	-153	189	393	-69433	85782	178576	-69420	17775	804
#6 Wing	454.9		w	-76	186	401	-34717	84571	182205	-34704	16563	4433
Rotor Group												
Rotor	1494.2	3131.7	n	305	194	319	456134	289727	476363	456177	66344	-107562
Rotor	1494.2		n	-305	194	319	-456134	289727	476363	-456092	66344	-107562
Spinner	71.7		n	305	194	316	21889	13903	22625	21891	3184	-5396
Spinner	71.7		n	-305	194	316	-21889	13903	22625	-21887	3184	-5396
Tail Group												
Vertical Tail	358.2	540.1	f	0	238	783	0	85345	280619	10	31792	140632
Horizontal Tail	91.0		f	52	238	783	4690	21670	71252	4693	8072	35708
Horizontal Tail	91.0		f	-52	238	783	-4690	21670	71252	-4688	8072	35708
Body Group												
#1 Body	1421.6	5686.4	f	0	111	254	0	158224	361437	41	-54312	-194135
#2 Body	1421.6		f	0	111	323	0	158224	459175	41	-54312	-96396
#4 Body	1421.6		f	0	111	486	0	158224	690273	41	-54312	134702
#4 Body	1421.6		f	0	111	566	0	158224	804324	41	-54312	248752
Alighting Gear Group												
Main Landing Gr	376.7	1029.9	f	86	84	463	32509	31639	174363	32520	-24672	27165
Main Landing Gr	376.7		f	-86	84	463	-32509	31639	174363	-32498	-24672	27165
Aux. Landing Gr	276.6		f	0	80	57	0	22128	15699	8	-19225	-92398
Nacelle Group												
Nacelle	349.6	1323.1	n	313	183	395	109255	63984	138130	109265	11717	1504
Nacelle	349.6		n	-313	183	395	-109255	63984	138130	-109245	11717	1504
Conversion Spin	98.3		n	288	192	404	28268	18840	39717	28271	4144	1301
Conversion Spin	98.3		n	-288	192	404	-28268	18840	39717	-28266	4144	1301
Pylon Support	213.7		n	302	194	397	64585	41406	84925	64591	9464	1429

Table 2. System weights and coordinates - cruise mode. (Continued)

COMPONENT	INDIVIDUAL WEIGHT	GROUP WEIGHT	LOCATION				MOMENT ABOUT 0,0,0				MOMENT ABOUT C.G.			
			C	BL	WL	FS	BL.in.lbs	WL.in.lbs	FS.in.lbs	BL.in.lbs	WL.in.lbs	FS.in.lbs	BL.in.lbs	FS.in.lbs
Pylon Support	213.7		n	-302	194	397	-64585	41406	84925	-64579	9464	1429		
Air Induction Group		107.2								0	0	0		
Air Induction Sys.	40.2		n	313	169	375	12563	6810	15058	12564	800	-653		
Air Induction Sys.	40.2		n	-313	169	375	-12563	6810	15058	-12562	800	-653		
Bypass System	13.4		n	305	168	386	4091	2247	5177	4091	244	-60		
Bypass System	13.4		n	-305	168	386	-4091	2247	5177	-4090	244	-60		
Propulsion Group		2599.9								0	0	0		
Engine	1017.2		n	313	169	407	317889	171876	413685	317918	19800	16156		
Engine	1017.2		n	-313	168	407	-317889	170831	413685	-317860	18754	16156		
Exhaust System	15.4		n	310	180	453	4776	2772	6971	4777	470	953		
Exhaust System	15.4		n	-310	180	453	-4776	2772	6971	-4776	470	953		
Ejector	19.2		n	305	168	422	5861	3220	8097	5862	349	593		
Ejector	19.2		n	-305	168	422	-5861	3220	8097	-5861	349	593		
Starter	51.8		n	312	166	390	16180	8601	20224	16181	857	-20		
Starter	51.8		n	-312	166	390	-16180	8601	20224	-16178	857	-20		
Fuel System	196.4		w	167	189	398	32848	37128	78127	32854	7773	1392		
Fuel System	196.4		w	-167	189	398	-32848	37128	78127	-32842	7773	1392		
Drive System		2820.3								0	0	0		
Transmission	897.5		n	306	190	361	274917	170749	324205	274943	36576	-26525		
Transmission	897.5		n	-306	190	361	-274917	170749	323746	-274892	36576	-26984		
Xmsn Support	74.5		n	299	195	380	22280	14510	28277	22282	3379	-818		
Xmsn Support	74.5		n	-296	195	380	-22058	14502	28277	-22056	3372	-818		
Pivot Box	181.0		n	315	194	411	57075	35161	74427	57080	8100	3691		
Pivot Box	181.0		n	-315	194	411	-57037	35159	74427	-57032	8099	3691		
Mast	199.6		n	305	194	347	60919	38694	69300	60924	8861	-8685		
Mast	199.6		n	-305	194	347	-60919	38694	69300	-60913	8861	-8685		
Pylon Shaft	17.8		n	324	195	379	5766	3463	6742	5767	802	-215		
Pylon Shaft	17.8		n	-324	195	379	-5766	3463	6742	-5766	802	-215		
Wing Shaft	39.9		w	153	189	420	6090	7524	16758	6091	1559	1165		
Wing Shaft	39.9		w	-153	189	420	-6090	7524	16758	-6089	1559	1165		
Flight Controls Group		1881.0								0	0	0		
Control Wire Wt	154.7		w	153	174	386	23619	26924	59684	23623	3790	-787		

Table 2. System weights and coordinates - cruise mode. (Continued)

COMPONENT	INDIVIDUAL WEIGHT	GROUP WEIGHT	LOCATION				MOMENT ABOUT 0,0,0				MOMENT ABOUT C.G.			
			BL	WL	FS	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	WL in.lbs	FS in.lbs
Control Wire Wt	154.7		f	0	174	402	0	26923	62151			4	3790	1682
Control Wire Wt	154.7		w	-153	174	386	-23618	26923	59683			-23614	3790	-787
Rotating Control	178.6		n	305	193	342	54508	34454	61092			54513	7760	-8687
Rotating Control	178.6		n	-305	193	342	-54508	34454	61092			-54503	7760	-8687
Flap Actuator	46.7		w	153	189	435	7128	8807	20334			7130	1825	2083
Flap Actuator	46.7		w	-153	189	435	-7128	8807	20334			-7127	1825	2083
Rudder Actuator	30.0		f	0	238	783	0	7148	23502			1	2663	11778
Elevator Actuator	18.8		f	52	238	783	970	4479	14728			970	1669	7381
Elevator Actuator	18.8		f	-52	238	783	-970	4479	14728			-969	1669	7381
Rotor Actuator	239.8		n	305	194	373	73206	46499	89405			73213	10648	-4310
Rotor Actuator	239.8		n	-305	194	373	-73206	46499	89405			-73199	10648	-4310
Conversion Actuator	209.6		n	282	190	371	59062	39754	77793			59068	8425	-4100
Conversion Actuator	209.6		n	-289	190	371	-60567	39754	77793			-60561	8425	-4100
Hydraulic Group		579.7										0	0	0
#1 Hydraulic	193.2		w	153	189	409	29495	36440	79004			29501	7551	3487
#2 Hydraulic	193.2		f	0	183	425	0	35411	82087			6	6521	6570
#3 Hydraulic	193.2		w	-153	189	409	-29495	36440	79004			-29490	7551	3487
Electrical Group		533.1										0	0	0
#1 Electrical	177.7		w	153	179	386	27124	31866	68543			27129	5299	-904
#2 Electrical	177.7		f	0	174	402	0	30920	71378			5	4353	1931
#3 Electrical	177.7		w	-153	179	386	-27124	31866	68543			-27119	5299	-904
Fixed Equipment*		6010.0										0	0	0
#1 Equipment	1502.5		f	0	111	260	0	167228	391285			43	-57403	-195903
#2 Equipment	1502.5		f	0	111	347	0	167228	521713			43	-57403	-65474
#3 Equipment	1502.5		f	0	111	521	0	167228	782570			43	-57403	195382
#4 Equipment	1502.5		f	0	111	608	0	167228	912998			43	-57403	325811
Contingency		289.7										0	0	0
Contingency	289.7		f	0	111	393	0	32245	113736			8	-11069	512
Total Empty WT		29261.4		0	153	401	-1244	4481863	11733953			0	0	
Useful Load		14353.4										0	0	0
Crew	635.0		f	0	106	99	0	67056	62711			18	-27880	-185451

Table 2. System weights and coordinates - cruise mode. (Continued)

COMPONENT	INDIVIDUAL WEIGHT	GROUP WEIGHT	C	LOCATION			MOMENT ABOUT 0,0,0			MOMENT ABOUT C.G.		
				BL	WL	FS	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	WL in.lbs	FS in.lbs
Crew	636.0		f	0	106	99	0	67056	62711	18	-27880	-185451
Payload	2267.0		f	0	111	236	0	252317	533981	65	-86610	-351979
Payload	2267.0		f	0	111	314	0	252317	711974	65	-86610	-173985
Payload	2266.0		f	0	111	471	0	252206	1067491	65	-86572	181922
Payload	1200.0		f	0	111	550	0	133560	659526	34	-45846	190558
Fuel	1397.1		w	244	192	390	340358	267906	544767	340398	59029	-1239
Fuel	1397.1		w	91	186	406	127101	260464	567059	127141	51587	21053
Fuel	1397.1		w	-244	192	390	-340358	267906	544767	-340319	59029	-1239
Fuel	1397.1		w	-91	186	406	-127101	260464	567059	-127061	51587	21053
Trapped Fluids	65.0		w	167	189	398	10866	12282	25843	10868	2571	461
Trapped Fluids	65.0		w	-167	189	398	-10866	12282	25843	-10864	2571	461
Gross Weight		43614.8		0	150	391	-1244	6520622	17044975			

GROUP	FE (sq ft)	DRAG LOAD	C	LOCATION			MOMENT ABOUT 0,0,0			MOMENT ABOUT C.G.		
				BL	WL	FS	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	WL in.lbs	FS in.lbs
Fuselage	5.2015322	1534.5	f	0	150	391	-44	229408	599675	0	-19	-53
Wing/Fuse	0.1851308	54.6	w	57	185	409	3113	10117	22311	11	6	1
Wing/Fuse	0.1851308	54.6	w	-57	185	409	-3113	10117	22311	-11	6	1
Wing	1.5084531	1279.6	w	153	189	393	195317	241306	502337	230	53	-13
Wing	1.5084531	1279.6	w	-153	189	393	-195317	241306	502337	-230	53	-13
Nacelle/Wing	0.0116264	3.4	w	273	193	377	937	661	1292	3	0	0
Nacelle/Wing	0.0116264	3.4	w	-273	193	377	-937	661	1292	-3	0	0
Nacelle	0.6799529	200.6	n	304	194	377	60899	38883	75545	206	28	-17
Nacelle	0.6799529	200.6	n	-304	194	377	-60899	38883	75545	-206	28	-17
H Tail	0.3168475	93.5	f	98	238	783	9115	22270	73226	31	27	121
H Tail	0.3168475	93.5	f	-98	238	783	-9115	22270	73226	-31	27	121
V Tail	0.7662354	226.0	f	0	238	783	0	53856	177083	0	65	293
Misc	3	885.0	f	0	150	391	-25	132312	345864	0	-11	-31
Resultant Drag	14.371789	5908.9		0	176	418	-69	1042052	2472042			

Table 2. System weights and coordinates - cruise mode. (Continued)

COMPONENT	INDIVIDUAL LIFT	GROUP LIFT	C	LOCATION			MOMENT ABOUT 0,0,0			MOMENT ABOUT C.G.		
				BL	WL	FS	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	WL in.lbs	FS in.lbs
Wing Group		43991										
#1 Wing Lift	7331.8018		w	229	191	385	1678689	1402163	2819793	1679001	2791780	-120291
#2 Wing Lift	7331.8018		w	153	189	393	1119126	1382635	2878284	1119438	259650	-61801
#3 Wing Lift	7331.8018		w	76	186	401	559563	1363106	2936774	559875	240121	-3310
#4 Wing Lift	7331.8018		w	-229	191	385	-1678689	1402163	2819793	-1678378	279178	-120291
#5 Wing Lift	7331.8018		w	-153	189	393	-1119126	1382635	2878284	-1118815	259650	-61801
#6 Wing Lift	7331.8018		w	-76	186	401	-559563	1363106	2936774	-559251	240121	-3310
Resultant Lift	43990.811			0	189	393	0	8295809	17269702			

COMPONENT	INDIVIDUAL THRUST	GROUP THRUST	C	LOCATION			MOMENT ABOUT 0,0,0			MOMENT ABOUT C.G.		
				BL	WL	FS	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	WL in.lbs	FS in.lbs
Wing Group		5909										
#1 Rotor Thrust	2954.4388		n	305	194	319	901931	572888	941930	902057	120367	-242813
#2 Rotor Thrust	2954.4388		n	-305	194	319	-901931	572888	941930	-901805	120367	-242813
Resultant Thrust	5908.8775			0	194	319	0	1145776	1883859			

Moment Sum about Point A

Moment Sum about Point B

Table 3. System weights and coordinates - hover mode.

COMPONENT	INDIVIDUAL WEIGHT	GROUP WEIGHT	LOCATION				MOMENT ABOUT 0,0,0				MOMENT ABOUT C.G.			
			C	BL	WL	FS	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	WL in.lbs	FS in.lbs		
Wing Group														
#1 Wing	454.9	2729.3	w	229	191	385	104150	86994	174947	104163	13761	-7203		
#2 Wing	454.9		w	153	189	393	69433	85782	178576	69446	12550	-3574		
#3 Wing	454.9		w	76	186	401	34717	84571	182205	34729	11338	55		
#4 Wing	454.9		w	-229	191	385	-104150	86994	174947	-104138	13761	-7203		
#5 Wing	454.9		w	-153	189	393	-69433	85782	178576	-69421	12550	-3574		
#6 Wing	454.9		w	-76	186	401	-34717	84571	182205	-34704	11338	55		
Rotor Group														
Rotor	1494.2	3131.7	n	305	279	404	456457	417068	603693	456498	176523	5388		
Rotor	1494.2		n	-305	279	404	-456457	417068	603693	-456416	176523	5388		
Spinner	71.7		n	305	282	404	21904	20248	28969	21906	8705	259		
Spinner	71.7		n	-305	282	404	-21904	20248	28969	-21902	8705	259		
Tail Group														
Vertical Tail	358.2	540.1	f	0	238	783	0	85345	280619	10	27678	137185		
Horizontal Tail	91.0		f	52	238	783	4690	21670	71252	4693	7028	34832		
Horizontal Tail	91.0		f	-52	238	783	-4690	21670	71252	-4688	7028	34832		
Body Group														
#1 Body	1421.6	5686.4	f	0	111	254	0	158224	361437	0	0	0		
#2 Body	1421.6		f	0	111	323	0	158224	459175	39	-70641	-207817		
#4 Body	1421.6		f	0	111	486	0	158224	690273	39	-70641	-110078		
#4 Body	1421.6		f	0	111	566	0	158224	804324	39	-70641	121019		
Alighting Gear Group														
Main Landing Gr	376.7	1029.9	f	86	84	463	32509	31639	174363	32519	-28999	23540		
Main Landing Gr	376.7		f	-86	84	463	-32509	31639	174363	-32498	-28999	23540		
Aux. Landing Gr	276.6		f	0	80	57	0	22128	15699	8	-22402	-95060		
Nacelle Group														
Nacelle	349.6	1323.1	n	313	203	403	109330	71002	140927	109340	14720	936		
Nacelle	349.6		n	-313	203	403	-109330	71002	140927	-109321	14720	936		
Conversion Spin	98.3		n	288	192	405	28290	18845	39860	28292	3019	498		
Conversion Spin	98.3		n	-288	192	405	-28290	18845	39860	-28287	3019	498		
Pylon Support	213.7		n	303	200	404	64631	42805	86323	64637	8410	770		

Table 3. System weights and coordinates - hover mode. (Continued)

COMPONENT	INDIVIDUAL		GROUP WEIGHT	C	LOCATION			MOMENT ABOUT 0,0,0			MOMENT ABOUT C.G.		
	WEIGHT				BL	WL	FS	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	WL in.lbs	FS in.lbs
Pylon Support	213.7		107.2	n	-303	200	404	-64631	42805	86323	-64625	8410	770
Air Induction Group													
Air Induction Sys.	40.2			n	313	224	402	12572	8990	16159	12573	2518	62
Air Induction Sys.	40.2			n	-313	224	402	-12572	8990	16159	-12571	2518	62
Bypass System	13.4			n	305	212	402	4094	2835	5385	4094	678	19
Bypass System	13.4			n	-305	212	402	-4094	2835	5385	-4093	678	19
Propulsion Group			2599.9										
Engine	1017.2			n	313	192	402	318109	194810	408852	318137	31049	1533
Engine	1017.2			n	-313	192	402	-318109	194810	408852	-318081	31049	1533
Exhaust System	15.4			n	310	145	403	4780	2240	6204	4780	-239	38
Exhaust System	15.4			n	-310	145	403	-4780	2240	6204	-4779	-239	38
Ejector	19.2			n	305	176	402	5866	3384	7716	5866	293	27
Ejector	19.2			n	-305	176	402	-5866	3384	7716	-5865	293	27
Starter	51.8			n	313	208	402	16191	10763	20808	16192	2423	65
Starter	51.8			n	-313	208	402	-16191	10763	20808	-16189	2423	65
Fuel System	196.4			w	167	189	398	32848	37128	78127	32853	5518	-497
Fuel System	196.4			w	-167	189	398	-32848	37128	78127	-32843	5518	-497
Drive System			2820.3										
Transmission	897.5			n	307	237	404	275111	212461	362328	275136	67979	2961
Transmission	897.5			n	-307	237	404	-275111	212461	362328	-275086	67979	2961
Xmsn Support	74.5			n	299	218	404	22296	16225	30088	22298	4239	276
Xmsn Support	74.5			n	-296	218	404	-22074	16217	30088	-22072	4231	276
Pivot Box	181.0			n	316	187	404	57114	33866	73131	57119	4727	653
Pivot Box	181.0			n	-315	187	404	-57076	33865	73131	-57071	4725	653
Mast	199.6			n	305	251	404	60962	50021	80626	60967	17895	720
Mast	199.6			n	-305	251	404	-60962	50021	80626	-60956	17895	720
Pylon Shaft	17.8			n	324	220	404	5770	3913	7192	5771	1048	64
Pylon Shaft	17.8			n	-324	220	404	-5770	3913	7192	-5770	1048	64
Wing Shaft	39.9			w	153	189	420	6090	7524	16758	6091	1101	780
Wing Shaft	39.9			w	-153	189	420	-6090	7524	16758	-6089	1101	780
Flight Controls Group			1881.0										
Control Wire Wt	154.7			w	153	174	386	23619	26924	59684	0	0	0
											23623	2013	-2276

Table 3. System weights and coordinates - hover mode. (Continued)

COMPONENT	INDIVIDUAL WEIGHT	GROUP WEIGHT	LOCATION				MOMENT ABOUT 0,0,0				MOMENT ABOUT C.G.			
			C	BL	WL	FS	BL.in.lbs	WL.in.lbs	FS.in.lbs	BL.in.lbs	WL.in.lbs	FS.in.lbs	BL.in.lbs	FS.in.lbs
Control Wire Wt	154.7		f	0	174	402	0	26923	62151	4	2013	193		
Control Wire Wt	154.7		w	-153	174	386	-23618	26923	59683	-23614	2013	-2276		
Rotating Control	178.6		n	305	256	404	54546	45672	72127	54551	16927	630		
Rotating Control	178.6		n	-305	256	404	-54546	45672	72127	-54541	16927	630		
Flap Actuator	46.7		w	153	189	435	7128	8807	20334	7130	1288	1634		
Flap Actuator	46.7		w	-153	189	435	-7128	8807	20334	-7127	1288	1634		
Rudder Actuator	30.0		f	0	238	783	0	7148	23502	1	2318	11490		
Elevator Actuator	18.8		f	52	238	783	970	4479	14728	970	1453	7200		
Elevator Actuator	18.8		f	-52	238	783	-970	4479	14728	-969	1453	7200		
Rotor Actuator	239.8		n	305	225	404	73258	53984	96888	73264	15378	865		
Rotor Actuator	239.8		n	-305	225	404	-73258	53984	96888	-73251	15378	865		
Conversion Actuator	209.6		n	282	227	404	59108	47508	84593	59113	13772	682		
Conversion Actuator	209.6		n	-289	227	404	-60567	47508	84593	-60562	13772	682		
Hydraulic Group		579.7								0	0	0		
#1 Hydraulic	193.2		w	153	189	409	29495	36440	79004	29500	5331	1628		
#2 Hydraulic	193.2		f	0	183	425	0	35411	82087	5	4302	4711		
#3 Hydraulic	193.2		w	-153	189	409	-29495	36440	79004	-29490	5331	1628		
Electrical Group		533.1								0	0	0		
#1 Electrical	177.7		w	153	179	386	27124	31866	68543	27129	3258	-2614		
#2 Electrical	177.7		f	0	174	402	0	30920	71378	5	2312	221		
#3 Electrical	177.7		w	-153	179	386	-27124	31866	68543	-27119	3258	-2614		
Fixed Equipment*		6010.0								0	0	0		
#1 Equipment	1502.5		f	0	111	260	0	167228	391285	41	-74661	-210363		
#2 Equipment	1502.5		f	0	111	347	0	167228	521713	41	-74661	-79935		
#3 Equipment	1502.5		f	0	111	521	0	167228	782570	41	-74661	180921		
#4 Equipment	1502.5		f	0	111	608	0	167228	912998	41	-74661	311350		
Contingency		289.7								0	0	0		
Contingency	289.7		f	0	111	393	0	32245	113736	8	-14396	-2276		
Total Empty WT		29261.4		0	170	415	-1199	4982847	12153721	0	0	0		
Useful Load		14353.4								0	0	0		
Crew	635.0		f	0	106	99	0	67056	62711	17	-35173	-191563		

Table 3. System weights and coordinates - hover mode. (Continued)

COMPONENT	INDIVIDUAL WEIGHT	GROUP WEIGHT	LOCATION				MOMENT ABOUT 0,0,0				MOMENT ABOUT C.G.			
			C	BL	WL	FS	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	FS in.lbs
Payload	2267.0		f	0	111	236	0	252317	533981	62	-112650	-373797		
Payload	2267.0		f	0	111	314	0	252317	711974	62	-112650	-195804		
Payload	2266.0		f	0	111	471	0	252206	1067491	62	-112601	160113		
Payload	1200.0		f	0	111	550	0	133560	659526	33	-59630	179009		
Fuel	1397.1		w	244	192	390	340358	267906	544767	340397	42981	-14685		
Fuel	1397.1		w	91	186	406	127101	260464	567059	127140	35539	7606		
Fuel	1397.1		w	-244	192	390	-340358	267906	544767	-340320	42981	-14685		
Fuel	1397.1		w	-91	186	406	-127101	260464	567059	-127063	35539	7606		
Trapped Fluids	65.0		w	167	189	398	10866	12282	25843	10867	1825	-165		
Trapped Fluids	65.0		w	-167	189	398	-10866	12282	25843	-10864	1825	-165		
Gross Weight		43614.8		0	161	400	-1199	7021606	17464744					

GROUP	FE(sq ft)	DRAG LOAD	C	LOCATION				MOMENT ABOUT 0,0,0				MOMENT ABOUT C.G.			
				BL	WL	FS	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	WL in.lbs	FS in.lbs
Fuselage	5.2015322	1534.5	f	0	161	400	-42	247033	614443	0	-48	-78			
Wing/Fuse	0.1851308	54.6	w	57	185	409	3113	10117	22311	11	3	-1			
Wing/Fuse	0.1851308	54.6	w	-57	185	409	-3113	10117	22311	-11	3	-1			
Wing	1.5084531	1279.6	w	153	189	393	195317	241306	502337	230	28	-34			
Wing	1.5084531	1279.6	w	-153	189	393	-195317	241306	502337	-230	28	-34			
Nacelle/Wing	0.0116264	3.4	w	273	193	377	937	661	1292	3	0	0			
Nacelle/Wing	0.0116264	3.4	w	-273	193	377	-937	661	1292	-3	0	0			
Nacelle	0.6799529	200.6	n	304	194	377	60899	38883	75545	206	16	-26			
Nacelle	0.6799529	200.6	n	-304	194	377	-60899	38883	75545	-206	16	-26			
H Tail	0.3168475	93.5	f	98	238	783	9115	22270	73226	31	22	117			
H Tail	0.3168475	93.5	f	-98	238	783	-9115	22270	73226	-31	22	117			
V Tail	0.7662354	226.0	f	0	238	783	0	53856	177083	0	52	282			
Misc	3	885.0	f	0	161	400	-24	142477	354382	0	-28	-45			
Resultant Drag	14.371789	5908.9		0	181	422	-66	1069843	2495328						

Table 3. System weights and coordinates - hover mode. (Continued)

COMPONENT	INDIVIDUAL LIFT	GROUP LIFT	LOCATION			MOMENT ABOUT 0,0,0			MOMENT ABOUT C.G.			
			C	BL	WL	FS	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	WL in.lbs	FS in.lbs
43991												
Wing Group												
#1 Wing Lift	7331.8018		w	229	191	385	1678689	1402163	2819793	1678990	153651	-225469
#2 Wing Lift	7331.8018		w	153	189	393	1119126	1382635	2878284	1119427	134122	-166979
#3 Wing Lift	7331.8018		w	76	186	401	559563	1363106	2936774	559863	114594	-108489
#4 Wing Lift	7331.8018		w	-229	191	385	-1678689	1402163	2819793	-1678389	153651	-225469
#5 Wing Lift	7331.8018		w	-153	189	393	-1119126	1382635	2878284	-1118826	134122	-166979
#6 Wing Lift	7331.8018		w	-76	186	401	-559563	1363106	2936774	-559263	114594	-108489
Resultant Lift	43990.811			0	189	393	0	8295809	17269702			

COMPONENT	INDIVIDUAL THRUST	GROUP THRUST	C	LOCATION			MOMENT ABOUT 0,0,0			MOMENT ABOUT C.G.		
				BL	WL	FS	BL in.lbs	WL in.lbs	FS in.lbs	BL in.lbs	WL in.lbs	FS in.lbs
5909												
Wing Group												
# 1 Rotor Thrust	2954.4388		n	305	279	404	902569	824685	1193704	902690	321582	-33422
# 2 Rotor Thrust	2954.4388		n	-305	279	404	-902569	824685	1193704	-902448	321582	-33422
Resultant Thrust	5908.8775			0	279	404	0	1649370	2387408			

Table 3. System weights and coordinates - hover mode. (Concluded)

Tail Lift	-376	rad	deg					
Cyclic Vector	-0.028972		-1.6600					
Moment Sum about Point A								
HORIZONTAL VERTICAL								
COMPONENT	FORCE	BL	WL	FS	dWL	dFS	WING	BODY
Body Wt	-22784	0	115	401	-60	-29		627934
Wing Wt	-20830	0	212	400	37	-30	643450	
Body Drag	0	0	162	448	-13	18		0
Wing Drag	0	0	189	391	14	-39	0	
Rotor Thrust	0	0	279	404	104	-26	-1376300	
Wing Lift	0	0	189	393	14	-37	0	
Wing Download	-3876	0	189	403	14	-27	105026	
Tail Lift	0	0	238	783	63	353		0
Sum	0	20			moment	111	-627823	627934
				Reaction Force at B				
							14607	-14609

Moment Sum about Point B										
COMPONENT	HORIZONTAL		VERTICAL		WL	FS	dWL	dFS	WING	BODY
	FORCE	BL	FORCE	BL						
Body Wt	0	0	-22784	0	115	401	-60	-74		1652801
Wing Wt	0	0	-20830	0	212	400	37	-75	1580426	
Body Drag	0	0	0	0	162	448	-13	-27		0
Wing Drag	0	0	0	0	189	391	14	-84	0	
Rotor Thrust	0	0	47511	0	279	404	104	-71	-3513383	
Wing Lift	0	0	0	0	189	393	14	-82	0	
Wing Download	0	0	-3876	0	189	403	14	-72	279370	
Tail Lift	0	0	0	0	238	783	63	308		0
Sum	0		20				Moment	-786	-1653587	1652801
							Reaction Force at A		-38472	38453

nates (FS,WL,BL) of key "benchmarks" based on assumptions in GARP and mass distributions. For example, if the V-22 is used as a model, the hub flap axis is not the same as the hub mass center. Therefore, specific geometric "benchmark" notes are presented below that will facilitate 3-view/3D layouts based on the criteria used in generating the tiltrotor pre-design.

Each of the systems listed in the weight summary (Tables 2 and 3) is located in terms of fuselage station, buttock line and water line using the sign convention defined in Figure 8.

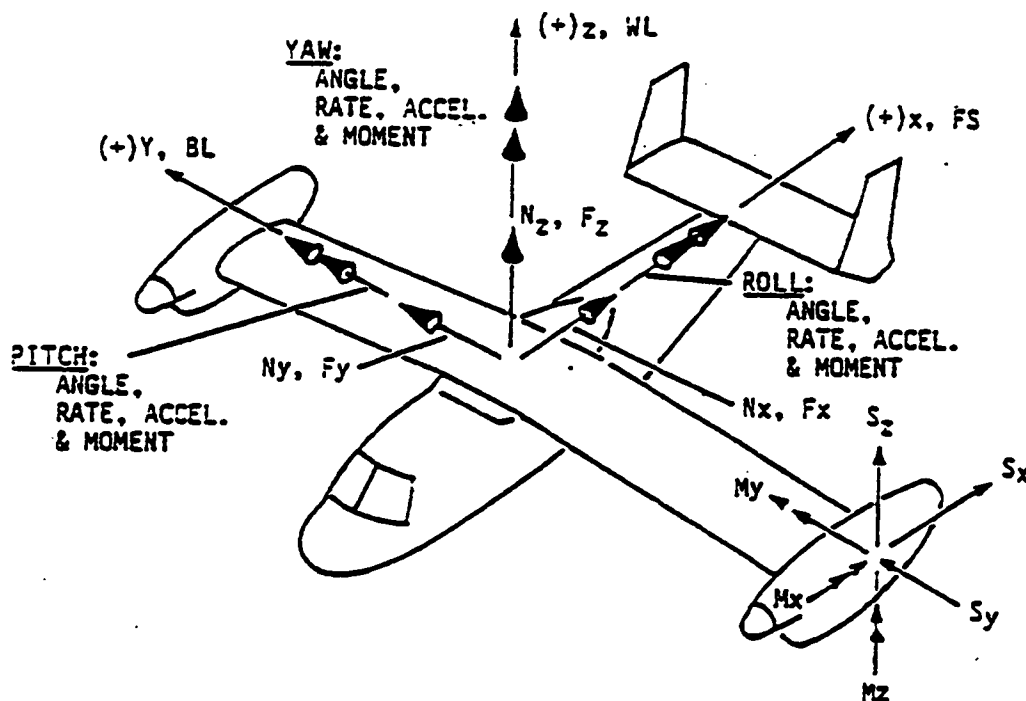
Lift - Propulsion System

Tables 4 and 5 provide geometry data for the lift-propulsion system in the cruise and hover modes. Figure 9 shows the relationship of these points to each other. This geometry is included for information to show the key relationships which constrain tiltrotor design. The wing and drive shaft are located relative to the rotor as set by blade to wing clearance and center of gravity (CG) and center of lift shift during transition from cruise

to hover mode. The allowable shift in center of gravity range for the vehicle is defined by "Z" in Figure 9. Maintaining these relationships is critical to any optimization process which might result in change to this basic geometry.

Landing Gear Placement, Tiltrotor

Table 6 lists the geometric constraints which place the landing gear. The needed input criteria and output derived parameters are given along with the related geometry sketch, Figure 10. Typical assumptions include: 1) tipback angle stability is one degree more than the maximum flare angle, and 2) a tipover angle of 25 degrees is selected as less than a military criterion because landing ramps normally will be stationary and level. Additional considerations that might change the gear placement are associated with overload short takeoff and one-wheel-up landings. Currently, a one-main-wheel-up landing probably will not cause the end of the pylon or outboard-flapped, low rotor to contact the ground. These items would be among those checked in more detail if aircraft pre-design were



2-E588

Figure 8. Tiltrotor sign convention.

Table 4. Geometry for nacelle - cruise mode

POINT	DESCRIPTOR	BL (in.)	FS (in.)	WL (in.)
A	WL of fuselage bottom skin (Specify WL Only)	0.00	404.00	60.00
B	WL of "wing platform" (or fuselage top skin)	0.00	404.00	174.00
C	Reference cross-shaft intercept @ CL	0.00	436.09	183.26
D	Conversion pivot; SPECIFY FS ONLY!	305.28	404.00	193.92
E	Projection of wing LE to BL of conv. pivot	305.28	355.22	196.47
F	Projection of wing LE to CL of A/C	0.00	387.30	185.81
G	Projection of wing TE to CL of A/C	0.00	472.89	181.33
H	Projection of wing TE to BL of conv. pivot	305.28	440.80	191.99
I	Most aft point of nacelle (No IR supp.)	305.28	468.28	193.92
J	Reference engine axis parallel to rotor shaft	314.30	404.00	157.74
K	Nacelle bottom point	314.30	404.00	139.87
L	Reference zero dihedral / sweep at conv. piv. BL	305.28	436.09	183.26
M	Ref. sweep and zero dihedral at conv. piv. BL	305.28	404.00	183.26
N	Ref. dihedral and zero sweep at conv. piv. BL	305.28	436.09	193.92
O	Rotor flap and mast axes intercept	305.28	315.56	193.92
P	Most fwd. point of nacelle (body-like nose)	305.28	273.74	193.92
Q	Rotor PCA - zero flapping with precon, inboard	69.32	303.20	193.92
R	Rotor PCA - full radius, inboard	69.00	315.56	193.92
S	BL tangent to fuselage max half-breadth	57.00	315.56	193.92
T	Rotor PCA - flapped back, w/precone, inboard	71.30	348.45	193.92
U	Rotor TE - full flapped back w/precone, inboard	71.30	367.68	178.89
V	Wing LE at closest proximity of rotor tip	71.30	379.68	188.31
W	Wing 1/4 M.A.C.	152.64	392.62	190.02
X	Outer spinner diameter point (old span ref.)	326.31	315.56	193.92
Y	Outer nacelle point (widest part of airframe)	332.17	404.00	157.74
Z	Reference - water line of the ground	0.00	436.09	30.00
@	Normal from conv. pivot axis to rotor hub			
ANGLE		(degrees)		
JDM	Engine cant angle	14.00		
MCL	Wing sweep angle	-6.00		
NCL	Wing dihedral angle	2.00		
ODC	Conversion pivot gearbox angle			
ODE	Wing incidence angle	3.00		
QOS	Maximum rotor flapping angle	11.00		
ROQ	Rotor precon angle	3.00		
RTS	90 - maximum blade tip pitch angle	38.00		
LENGTH		(inches)		
BDYWIDTH	Width of fuselage	114.00		
CB	Blade chord	30.50		
CLF	Clearance of rotor tip to fuselage BL (delta BL)	12.00		
CLW	Clearance of rotor tip to wing LE (delta FS)	12.00		
CWING	Wing chord	85.70		
ENGR	Engine radius	16.25		
OD	Pylon length (rotor flap axis to conv. pivot)	88.44		
OR	Rotor radius	236.28		

Table 4. Geometry for nacelle - cruise mode (concluded)

RATIO		(nd)
(BC/EH)	Half wing thickness to chord ratio	0.108
(ED/FG)	Wing tip chord to root chord ratio	1.000
(ED/EH)	Wing chord fraction for conversion pivot	0.570
(JY/ENGR)	Engine cowl to engine radius ratio	1.100
(OX/OR)	Spinner to rotor radius ratio	0.089
(PD/EH)	Nacelle forebody length to wing chord ratio	1.520
(PI/EH)	Nacelle length to wing chord ratio	2.270
(ST/SU)	Blade chord fract for pitch change axis (PCA) at tip	0.200

Table 5. Geometry for nacelle - hover mode

Pylon Incidence (Tilt) Angle:		90 degrees		Ref.
POINT	(DEFINITIONS: nacelle tilt shown above)	BL (in.)	FS (in.)	WL (in.)
Di	Location of conversion pivot	305.28	404.00	193.92
Li	Most aft point of nacelle (No IR supp.)			
Ji	Reference engine axis parallel to rotor shaft			
Ki	Nacelle bottom (forward) point			
Oi**	Rotor flap and mast axes intercept	311.45	404.00	282.14
Pi	Most fwd. point of nacelle (body-like nose)			
Xi	Outer spinner diameter point (old span ref.)			
Yi	Outer nacelle point (widest part of airframe)			
ANGLE		(degrees)		
OD(-M)#	Pylon dihedral (mast axis inboard = +)	-4.0**		

**approximate

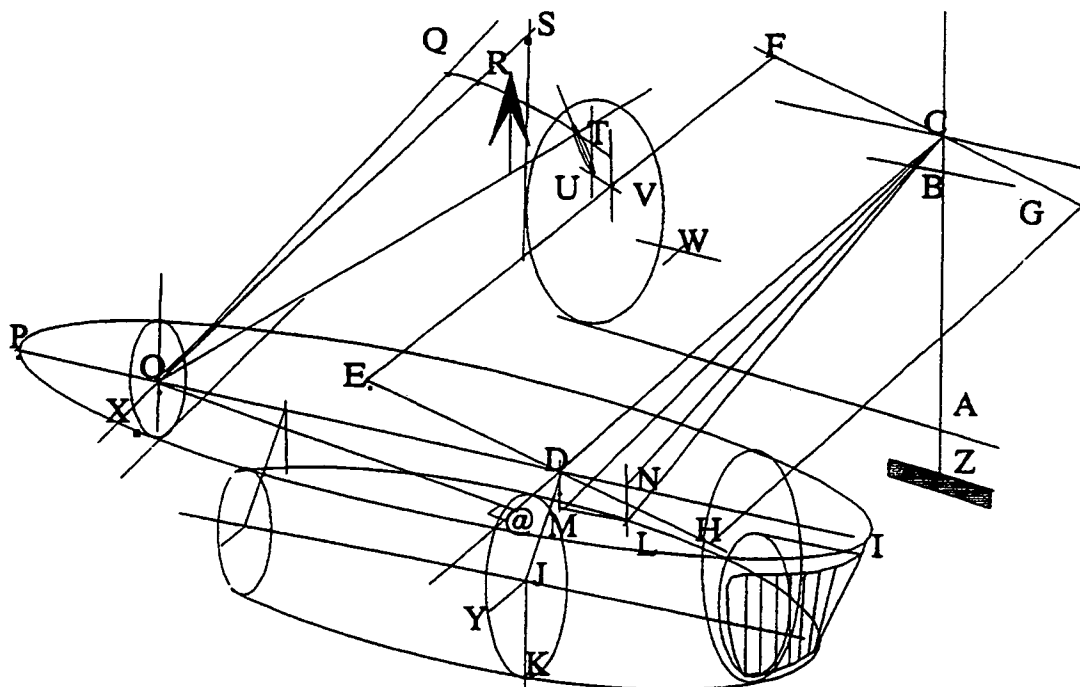
started but are probably not important for structural optimization work at this stage. Landing gear placement is important to critical loading conditions experienced on V-22 body and wing structures and, similarly, is likely to be important for the Model 940A.

LOADS

Requirements for preliminary wing and body shear and moment diagrams based on the GARP data led to a simple spreadsheet scheme for rolling up mass and trim airload effects for starting structural concept layouts. Additional criteria and loading conditions are needed to better allo-

cate strength and stiffness distributions through the components being studied. Preliminary criteria and weight algorithms, though based on simple parametrics, are referenced to a database of weights of components that had many load conditions considered in their design.

Preliminary design loads have been developed using the Bell ILAM (Integrated Loads Analysis Methodology) developed under IRAD. These loads were based on V-22 design loading conditions which were found to be critical for the wing and fuselage and have been modified to account for differences in geometry, aerodynamic characteristics, weight and performance between the

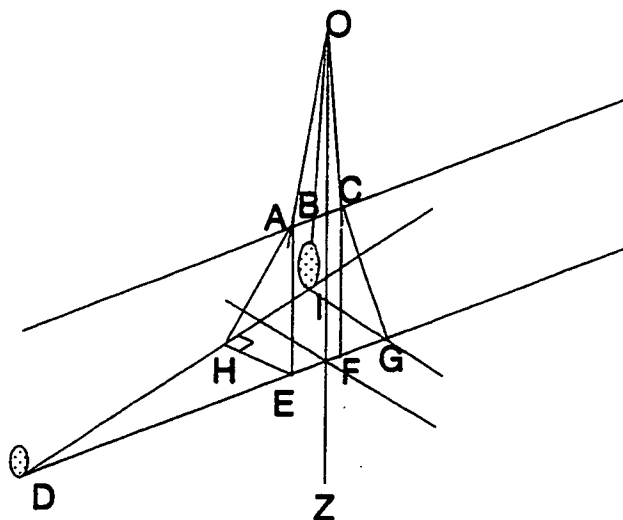


2-E589

Figure 9. Sketch of nacelle and related geometry.

Table 6. Geometry for landing gear ground contact points - helicopter mode

POINT	DESCRIPTOR	BL (in.)	FS (in.)	WL (in.)
O	Specified FS and WL location of both rotor hubs	0.0	404.0	282.1
A	Derived minimum FS @ location of most fwd CG	0.0	387.0	161.0
B	Specified WL height of mid CG	0.0	n.a.	161.0
B	Derived FS location of desired mid CG	0.0	399.8	161.0
C	Derived maximum FS @ location of most aft CG	0.0	412.5	161.0
D	Specified FS and WL of nose wheel grd. contact	0.0	57.0	30.0
E	Derived as same FS as A but at ground WL	0.0	387.0	30.0
F	Derived as same FS as C but at ground WL	0.0	412.5	30.0
G	Derived as maximum tipback FS at ground	0.0	450.0	30.0
H	Derived as maximum tipover normal to fwd CG	60.0	375.7	30.0
I	Derived FS and right BL; between main tires	74.0	450.0	30.0
ANGLES	(+ longitudinal swashplate motion nose up)	(degrees)		
AOZ	Specified swashplate angle allocated for fwd CG	8.00		
BOZ	Specified swashplate angle allocated for mid CG	2.00		
COZ	Specified swashplate angle allocated to aft CG	-4.00		
GCF	Specified min. tipback angle (flare +)	16.00		
HAE	Specified min. tipover angle (+ & -)	25.00		
EDH	Derived wheel plan half-angle at nose wheel	10.67		
GDI	Derived wheel plan h-angle at nose wheel (chk)	10.67		



2-E804

Figure 10. Sketch of landing gear placement parameters.

V-22 and the Model 940A aircraft. The resulting matrix of external loading conditions critical for the wing and fuselage are given in Table 7. The design speeds and load factors specified are as follows:

Design Speeds:

$V_C = 295$ kn eq. airspeed

$V_H = 325$ kn eq. airspeed

$V_D(1.2V_H) = 390$ kn eq. airspeed

Design maneuvering factors:

Maximum = 4.0

Minimum = -1.0

These speeds and load factors are more severe than that required by the FARs¹ ("Interim Airworthiness Criteria: Powered Lift Transport Category Aircraft"). The FARs¹ state that the maneuvering load factor in airplane mode for any weight may not be less than 2.50 except where limited by the maximum lift capability.

Note 1: Part 25 - Fixed wing
Part 29 - Helicopters

In addition, the design speeds listed above are representative of military-type power ratings and represent performance capabilities far in excess of those of the current V-22.

It was assumed that the V-22 critical loads could be scaled to the current aircraft by accounting for changes in wing and stabilizing surface aerodynamic characteristics, rotor geometry and rotational speeds, total aircraft drag, power and speed. For example, in the helicopter and conversion modes, the thrust and torque for the civil tiltrotor vehicle were calculated by assuming that the thrust coefficient (T/C) and torque coefficient (C_Q/S) were equal to the thrust and torque coefficients from the similar V-22 condition. In the airplane mode, the differences in thrust and power required to overcome drag were accounted for in the analysis. Wing stabilizing surface loads were scaled by assuming similar aerodynamic coefficients (C_L , $C_{L\alpha}$, C_D , C_M , etc). Additional constraints such as vertical load factor requirements were also imposed.

Eleven critical external design loads, which include forces and moments, for preliminary sizing are listed in Table 7. These loads are given in the right-handed, body-fixed coordinate system shown in Figure 8. The flight and jump takeoff loads are to be applied at the following points:

ITEM POINT of APPLICATION

Fuselage	ref. pt.
Right rotor	Right rotor hub
Right hub spring	Right rotor hub
Right nacelle	Right nacelle ref. pt.
Left rotor	Left rotor hub
Left hub spring	Left rotor hub
Left nacelle	Left nacelle ref. pt.
Right wing	Right wing aero center
Left wing	Left wing aero center
Horizontal tail	Horiz. tail aero center.
Vertical tail	Vertical tail aero center

LOAD FACTORS and ACCELERATIONS

The loads as described in the previous section are external loads resulting from aerodynamic forces. These forces result in linear and rotational accelerations about the three aircraft axes which can be obtained by applying the external forces to the aircraft, recognizing the inertia of the various systems and finding the equilibrium condition. The results of this transformation for the eleven conditions are shown in Table 8.

SHEAR and MOMENT DIAGRAMS

Once external loads and the balancing accelerations are known, then shear, moment and torque in each of the major components can be determined. This has been accomplished for this study. The input data and summary of results are shown in Tables 9 and 10 for the 2-G Jump Takeoff condition. These are the forces on the rotor mast at the hub location and the various surfaces which occur during the course of the specified maneuver. It can be seen that the wing and fuselage structural weight has been divided up in a rather arbitrary manner in order to allow determination of vehicle shear and moment for the various load conditions. Of the eleven load conditions developed, three were selected as adequate for this preliminary sizing of the wing and center fuselage area. These conditions were selected as

yielding maximum fuselage or wing bending for the purpose of this limited sizing study.

The rationale for selecting these three conditions are as follows:

2GJTO produces high wing bending because the entire vertical lift force is applied at the ends of the wing and wing air loads are negative due to the downward thrust of the rotor.

4G symmetrical pullup in airplane mode produces the maximum bending forces on the fuselage but is actually less critical on the wing than the 2G JTO because the lifting force is distributed along the span.

A symmetrical pullup with the nacelle at 75 degrees to the horizontal produces the maximum wing bending and shear because the 2G vertical thrust of the rotor and a full one "G" lift from the wing are combined.

Fuselage vertical shear and bending moments are shown in Figure 11 for the 2-G jump takeoff condition. Wing shear, moment and torque are shown in Figures 12 through 14.

Tables 11 and 12 provides the data for the 289 kn 4-G symmetric pull up condition together with Figures 15 through 18. Tables 13 and 14 provide the data for the 110 kn symmetric pull up 75° nacelle condition together with Figures 19 through 23.

DYNAMICS STIFFNESS CRITERIA

The fundamental wing bending frequencies for a Civil Tiltrotor vehicle must satisfy two criteria:

1. Sufficient separation from 1/rev to prevent high loads and track and balance problems.
2. Proper placement to assure proprotor aeroelastic stability.

As a very rough guide, a set of frequency ranges are specified in Table 15 for use in establishing acceptable stiffness ranges for preliminary design and structural optimization purposes. These frequency ranges were based on previous XV-15 and V-22 frequency placements. Local

Table 7. External loads for eleven flight conditions.

2.0 G Jump Takeoff on 6° Slope - Nose Up										
CG = 400 0 160										
Item	Force			Moments			Location			Moment Summary
	x	y	z	Roll	Pitch	Yaw	x	y	z	
Fuselage	0	0	0	0	0	0	5	0	-49	0
Right Rotor	-5097	0	48491	50945	0	-972084	4	305	119	-412579
Right Hubspring	0	0	0	0	-60000	0	4	305	119	-972084
Right Nacelle	0	0	0	0	0	0	3	313	43	0
Left Rotor	-5097	0	48491	-50945	0	972084	4	-305	119	-623277
Left Hub Spring	0	0	0	0	-60000	0	4	-305	119	-412579
Left Nacelle	0	0	0	0	0	0	3	-313	43	-60000
Right Wing	0	0	-4876	0	0	0	-7	153	29	0
Left Wing	0	0	-4876	0	0	0	-7	-153	29	34132
Horizontal Tail	0	0	0	0	0	0	383	0	78	0
Vertical Tail	0	0	0	0	0	0	383	0	78	0
Sum	-10194	0	87230	0	-120000	0				-876894
										-1595361

2.0 G Jump Takeoff on 6° Slope - Nose Down										
CG = 400 0 160										
Item	Force			Moments			Location			Moment Summary
	x	y	z	Roll	Pitch	Yaw	x	y	z	
Fuselage	0	0	0	0	0	0	5	0	-49	0
Right Rotor	5097	0	48491	-50945	0	-972084	4	305	119	800507
Right Hubspring	0	0	0	0	-60000	0	4	305	119	-972084
Right Nacelle	0	0	0	0	0	0	3	313	43	0
Left Rotor	5097	0	48491	50945	0	972084	4	-305	119	-60000
Left Hub Spring	0	0	0	0	-60000	0	4	-305	119	800507
Left Nacelle	0	0	0	0	0	0	3	-313	43	-60000
Right Wing	0	0	-4876	0	0	0	-7	153	29	0
Left Wing	0	0	-4876	0	0	0	-7	-153	29	34132
Horizontal Tail	0	0	0	0	0	0	383	0	78	0
Vertical Tail	0	0	0	0	0	0	383	0	78	0
Sum	10194	0	87230	0	-120000	0				1549278
										1595361

Table 7. External loads for eleven flight conditions. (Continued)

2.0G Jump Takeoff on 6° Slope - Right Wing Up										
CG = 400 0 160										
Item	Force			Moments			Location			Moment Summary
	x	y	z	Roll	Pitch	Yaw	x	y	z	
Fuselage	0	0	0	0	0	0	5	0	-49	0
Right Rotor	0	5097	48491	0	-50945	-972084	4	305	119	15396298
Right Hub Spring	0	0	0	-60000	0	0	4	305	119	-60000
Right Nacelle	0	0	0	0	0	0	3	313	43	0
Left Rotor	0	5097	48491	0	50945	972084	4	-305	119	-1.42E+7
Left Hub Spring	0	0	0	-60000	0	0	4	-305	119	-60000
Left Nacelle	0	0	0	0	0	0	3	-313	43	0
Right Wing	0	0	-4876	0	0	0	-7	153	29	-746028
Left Wing	0	0	-4876	0	0	0	-7	-153	29	746028
Horizontal Tail	0	0	0	0	0	0	383	0	78	0
Vertical Tail	0	0	0	0	0	0	383	0	78	0
Sum	0	10194	87230	-120000	0	0				1093086 456192 40776

2.0G Jump Takeoff on 6° Slope - Right Wing Down										
CG = 400 0 160										
Item	Force			Moments			Location			Moment Summary
	x	y	z	Roll	Pitch	Yaw	x	y	z	
Fuselage	0	0	0	0	0	0	5	0	-49	0
Right Rotor	0	-5097	48491	0	50945	-972084	4	305	119	14183212
Right Hub Spring	0	0	0	-60000	0	0	4	305	119	-60000
Right Nacelle	0	0	0	0	0	0	3	313	43	0
Left Rotor	0	-5097	48491	0	-50945	972084	4	-305	119	-1.54E+7
Left Hub Spring	0	0	0	-60000	0	0	4	-305	119	-60000
Left Nacelle	0	0	0	0	0	0	3	-313	43	0
Right Wing	0	0	-4876	0	0	0	-7	153	29	-746028
Left Wing	0	0	-4876	0	0	0	-7	-153	29	746028
Horizontal Tail	0	0	0	0	0	0	383	0	78	0
Vertical Tail	0	0	0	0	0	0	383	0	78	0
Sum	0	-10194	87230	-120000	0	0				-1333086 456192 -40776

Table 7. External loads for eleven flight conditions. (Continued)

50 Fps Gust in Helicopter Mode at 80kn										
n										
CG = 400 0 160										
Item	Force			Moments			Location			Moment Summary
	x	y	z	Roll	Pitch	Yaw	x	y	z	
Fuselage	72	-10	-224	-296	66712	3897	5	0	-49	194 62064 3847
Right Rotor	4713	-3007	40402	0	-33298	-762658	4	305	119	11964777 689157 -774686
Right Hubspring	0	0	0	-31052	70783	0	4	305	119	-31052 70783 0
Right Nacelle	1261	-24	-622	-266	114656	441	3	313	43	-195984 167013 384974
Left Rotor	4281	2576	40400	0	-32418	742493	4	-305	119	-1.20E+7 638621 2092750
Left Hub Spring	0	0	0	35256	65359	0	4	-305	119	35256 65359 0
Left Nacelle	1261	-24	-622	-266	112537	441	3	-313	43	193388 164894 -384236
Right Wing	620	0	6472	0	-118086	0	-7	153	29	990216 -145410 -194060
Left Wing	654	0	6219	0	-115572	0	-7	-153	29	-951507 -140139 100062
Horizontal Tail	-106	0	853	294	1	2	383	0	78	294 318432 16220
Vertical Tail	24	-9	0	0	-1	0	383	0	78	-702 1871 -3447
Sum	12780	-498	92878	3670	130673	-15384				-10576 1892645 1241424

110kn Symmetrical Pull-up, 75° Nacelle Incidence										
CG = 400 0 160										
Item	Force			Moments			Location			Moment Summary
	x	y	z	Roll	Pitch	Yaw	x	y	z	
Fuselage	-124	530	2720	40592	157558	-92602	5	0	-49	14622 177234 -89952
Right Rotor	-2667	403	44175	273692	-44595	-1.0E+6	-18	305	116	13793815 -1149117 -1028686
Right Hubspring	0	0	0	-91031	82987	-24392	-18	305	116	-91031 82987 -24392
Right Nacelle	1850	1195	-290	12439	74620	20267	1	313	40	-30531 148330 585712
Left Rotor	-5986	2452	43842	-81269	-13242	303299	-5	-305	116	-1.32E+7 -926828 -1582579
Left Hub Spring	0	0	0	21481	112006	5756	-5	-305	116	21481 112006 5756
Left Nacelle	1850	1196	-290	12440	41120	-20267	1	-313	40	151050 114830 -583321
Right Wing	-2874	0	11576	0	-91445	0	-7	153	29	1771128 -255823 899562
Left Wing	-1422	0	11395	2	-60387	0	-7	-153	29	-1743433 -181390 -217566
Horizontal Tail	-211	42	967	-18823	4	7	383	0	78	-15547 353907 48376
Vertical Tail	-28	1495	0	0	1	0	383	0	78	116610 -2183 572585
Sum	-9612	7313	114095	169523	258627	-829364				819517 -1526047 -1414505

Table 7. External loads for eleven flight conditions. (Continued)

185 kn , 3.0G Symmetrical Pull-Up In Conversion Mode

CG = 391 0 149

Item	Force			Moments			Location			Moment Summary		
	x	y	z	Roll	Pitch	Yaw	x	y	z	Roll (Mx)	Pitch (My)	Yaw (Mz)
Fuselage	168	-12	5299	-261	807549	3798	14	0	-38	195	875351	3630
Right Rotor	-3928	-390	2004	376631	0	0	-72	305	45	970301	-321048	28080
Right Hubspring	0	0	0	0	29290	-8814	-72	305	45	0	29290	-8814
Right Nacelle	-283	-24	3579	-260	126325	429	4	313	34	1119151	131019	-85982
Left Rotor	-3776	386	1979	-363615	0	0	-72	-305	45	-949840	-312408	-1209680
Left Hub Spring	0	0	0	0	26578	9356	-72	-305	45	0	26578	9356
Left Nacelle	-283	-24	3579	-258	125161	430	4	-313	34	-1121301	129855	86649
Right Wing	-7266	0	57358	0	-1.2E+6	0	2	153	40	8775774	-1379999	2274258
Left Wing	-6881	0	57279	0	-1.2E+6	0	2	-153	40	-8763687	-1366602	-1052793
Horizontal Tail	234	0	-429	710	5021	-7	392	0	89	710	-142321	-36809
Vertical Tail	138	-145	0	0	43	0	392	0	89	-12905	12325	-56840
Sum	-21877	-209	130648	12947	-1.3E+6	5192				18398	-2317960	-47945

289kn , 4.0G Symmetrical Pull-Up In Airplane Mode

CG = 391 0 149

Item	Force			Moments			Location			Moment Summary		
	x	y	z	Roll	Pitch	Yaw	x	y	z	Roll (Mx)	Pitch (My)	Yaw (Mz)
Fuselage	-17	-113	16085	-3799	1670202	35682	14	0	-38	495	1896038	34100
Right Rotor	-2177	48	1152	293292	0	0	-72	305	45	646812	-180909	-3456
Right Hubspring	0	0	0	0	174110	-63054	-72	305	45	0	174110	-63054
Right Nacelle	532	-203	5648	-2217	247599	3674	4	313	34	1758705	288279	165122
Left Rotor	-2038	-104	1118	-273333	0	0	-72	-305	45	-619003	-172206	-630406
Left Hub Spring	0	0	0	0	166788	69020	-72	-305	45	0	166788	69020
Left Nacelle	532	-203	5648	-2217	246138	3674	4	-313	34	-1776943	286818	-159398
Right Wing	-2931	0	49495	1	-742401	0	2	153	40	7572736	-760651	917403
Left Wing	-1833	0	46748	5	-691059	0	2	-153	40	-7152439	-670883	-280449
Horizontal Tail	-1578	-8	9761	-352019	8	5	392	0	89	-352731	3685878	238303
Vertical Tail	247	-375	0	0	0	0	392	0	89	-33375	21983	-147000
Sum	-9263	-958	135655	-340287	1071385	49001				44257	4735245	140185

Table 7. External loads for eleven flight conditions. (Continued)

390 kn, 3.2G Left Rolling Pull-out In Airplane Mode										CG = 391 0 149			
Item	Force			Moments			Location			Moment Summary			
	x	y	z	Pitch	Roll	Yaw	x	y	z	Roll (Mx)	Pitch (My)	Yaw (Mz)	
Fuselage	1412	1951	-4033	93089	1492011	-724455	14	0	-38	18951	1381893	-697141	
Right Rotor	-2157	-712	1429	455127	0	0	-72	305	45	585932	-199953	51264	
Right Hub Spring	0	0	0	0	24272	-8814	-72	305	45	0	24272	-8814	
Right Nacelle	1137	3314	4919	35931	2625017	-59588	4	313	34	1688254	2683351	300453	
Left Rotor	-1963	285	874	-277677	0	0	-72	-305	45	-531422	-151263	-634939	
Left Hub Spring	0	0	0	0	-31052	-9763	-72	-305	45	0	-31052	-9763	
Left Nacelle	1137	3314	4919	35930	312460	-59588	4	-313	34	-1391041	370794	-393117	
Right Wing	8101	0	28969	-8	-278026	-1	2	153	40	4432249	103952	-2535614	
Left Wing	-5544	0	102713	-27	1.3E+6	0	2	-153	40	-1.57E+7	-1348597	-848232	
Horizontal Tail	139	8	-216	-60387	4	-2	392	0	89	-59675	-72297	-18133	
Vertical Tail	650	4007	0	0	2	0	392	0	89	356623	57852	1570744	
Sum	2912	12167	139574	281978	2812425	-862211				-1.03E+7	2818952	-3223292	

325 kn, -1.0G Symmetrical Push-Over In Airplane Mode										CG = 391 0 149			
Item	Force			Moments			Location			Moment Summary			
	x	y	z	Pitch	Roll	Yaw	x	y	z	Roll (Mx)	Pitch (My)	Yaw (Mz)	
Fuselage	1700	-62	-28823	-441	-761088	22524	14	0	-38	1915	-1229210	21656	
Right Rotor	-1152	-210	-1264	396211	0	0	-72	305	45	1241	39168	15120	
Right Hub Spring	0	0	0	0	-99802	41222	-72	305	45	0	-99802	41222	
Right Nacelle	2575	-82	-1017	-897	11635	1490	4	313	34	-322006	95117	786537	
Left Rotor	-1171	189	-1231	-409986	0	0	-72	-305	45	-26026	35937	-380131	
Left Hub Spring	0	0	0	0	-96818	-37697	-72	-305	45	0	-96818	-37697	
Left Nacelle	2575	-82	-1017	-897	17457	1489	4	-313	34	314636	100939	-784214	
Right Wing	1594	0	-455	0	642122	0	2	153	40	-69615	704972	-498922	
Left Wing	1965	0	-1084	0	-680443	0	2	-153	40	165852	-604011	300645	
Horizontal Tail	-7	-1	-8724	1805	-7	-1	392	0	89	1716	-3420438	678	
Vertical Tail	422	-218	0	0	0	0	392	0	89	-19402	37558	-85456	
Sum	8501	-466	-43615	-14205	-966944	29027				48311	-4436588	-620562	

Table 7. External loads for eleven flight conditions. (Concluded)

390kn Rudder Kick In Airplane Mode										CG = 391 0 149			
Item	Force			Moments			Location			Moment Summary			
	x	y	z	Roll	Pitch	Yaw	x	y	z	Roll (Mx)	Pitch (My)	Yaw (Mz)	
Fuselage	2089	-3679	-27679	-213491	5668	1272317	14	0	-38	-73689	-461220	1220811	
Right Rotor	-720	-1081	-147	399215	0	0	-72	305	45	305735	-21816	77832	
Right Hubspring	0	0	0	0	13696	56681	-72	305	45	0	13696	56681	
Right Nacelle	2832	-5313	2776	-57339	167053	95094	4	313	34	630907	274445	937602	
Left Rotor	-856	-1032	-85	-433886	0	0	-72	-305	45	-454401	-32400	-193624	
Left Hub Spring	0	0	0	0	-21967	53155	-72	-305	45	0	-21967	53155	
Left Nacelle	2832	-5313	2776	-57340	169644	95094	4	-313	34	-1106870	277036	-789918	
Right Wing	419	0	31272	2	-494986	0	2	153	40	4784618	-415682	-131147	
Left Wing	4645	0	36191	0	-527854	0	2	-153	40	-5537223	-269672	710685	
Horizontal Tail	282	-27	-519	108330	1	2	392	0	89	105927	-178349	-53728	
Vertical Tail	849	-7159	0	0	1	0	392	0	89	-637151	75562	-2806328	
Sum	12372	-23604	44585	-264509	-688744	1572343				-1982147	-760367	-917979	

Table 8. Translational and angular accelerations for eleven flight conditions.

2.0G Jump Takeoff on 6° Slope - Nose Up

COMPONENT	RATES (rad/s)	MOMENTS	FORCES	TRANSLATIONAL ACCELERATIONS
X	0	0	-10194	ax = -0.233726928
Y	0	-876894	0	ay = 0
Z	0	-1595361	87230	az = 2

INERTIAS	MOMENTS	PRODUCTS	Solve this matrix for angular accelerations (alphas)		
Ixx/Ixy	1.503E+09	-3802	1.503E+09	3.802E+03	-3.562E+07
Iyy/Ixz	1.267E+09	35620000	3.802E+03	1.267E+09	8.077E+04
Izz/Iyz	2.453E+09	-80767	-3.562E+07	8.077E+04	2.453E+09
					0E+00
					-3.388E+08
					-6.164E+08

RESULT (alpha x, y, z):

DET [A]	Alpha-x	Alpha-y	Alpha-z
4.66964E+27	-0.00596	-0.26741	-0.25138

2.0G Jump Takeoff on 6° Slope - Nose Down

COMPONENT	RATES (rad/s)	MOMENTS	FORCES	TRANSLATIONAL ACCELERATIONS
X	0	0	-10194	ax = -0.233726928
Y	0	-876894	0	ay = 0
Z	0	-1595361	87230	az = 2

INERTIAS	MOMENTS	PRODUCTS	Solve this matrix for angular accelerations (alphas)		
Ixx/Ixy	1.503E+09	-3802	1.503E+09	3.802E+03	-3.562E+07
Iyy/Ixz	1.267E+09	35620000	3.802E+03	1.267E+09	8.077E+04
Izz/Iyz	2.453E+09	-80767	-3.562E+07	8.077E+04	2.453E+09
					0E+00
					5.986E+08
					6.164E+08

RESULT (alpha x, y, z):

DET [A]	Alpha-x	Alpha-y	Alpha-z
4.66964E+27	0.00596	0.47247	0.25137

Table 8. Translational and angular accelerations for eleven flight conditions. (Continued)

2.0 G Jump Takeoff on 6° Slope - Right Wing Up

COMPONENT	RATES (rad/s)	MOMENTS	FORCES	TRANSLATIONAL ACCELERATIONS		
X	0	1093086	0	ax =	0	
Y	0	456192	10194	ay =	0.2337269288	
Z	0	40776	87230	az =	2	

INERTIAS MOMENTS PRODUCTS

Ixx/Ixy	1.503E+09	-3802	Solve this matrix for angular accelerations (alphas)			
Iyy/Ixz	1.267E+09	35620000	1.503E+09	3.802E+03	-3.562E+07	4.224E+08
Izz/Iyz	2.453E+09	-80767	3.802E+03	1.267E+09	8.077E+04	1.763E+08
			-3.562E+07	8.077E+04	2.453E+09	1.576E+07

RESULT (alpha x, y, z):

DET [A]	Alpha-x	Alpha-y	Alpha-z
4.66964E+27	-0.00596	-0.26741	-0.25138

2.0 G Jump Takeoff on 6° Slope - Right Wing Down

COMPONENT	RATES (rad/s)	MOMENTS	FORCES	TRANSLATIONAL ACCELERATIONS		
X	0	-1333086	0	ax =	0	
Y	0	456192	-10194	ay =	-0.233726928	
Z	0	-1595361-40776	87230	az =	2	

INERTIAS MOMENTS PRODUCTS

Ixx/Ixy	1.503E+09	-3802	Solve this matrix for angular accelerations (alphas)			
Iyy/Ixz	1.267E+09	35620000	1.503E+09	3.802E+03	-3.562E+07	-5.151E+08
Izz/Iyz	2.453E+09	-80767	3.802E+03	1.267E+09	8.077E+04	1.763E+08
			-3.562E+07	8.077E+04	2.453E+09	-1.576E+07

RESULT (alpha x, y, z):

DET [A]	Alpha-x	Alpha-y	Alpha-z
4.66964E+27	-0.34299	0.13913	-0.01141

Table 8. Translational and angular accelerations for eleven flight conditions. (Continued)

50 Fps Gust in Helicopter Mode at 80 kn

COMPONENT	RATES (rad/s)	MOMENTS	FORCES	TRANSLATIONAL ACCELERATIONS
X	-0.052356020	-10576	12780	ax = 0.2930184569
Y	0.0698080279	1892645	-498	ay = -0.011418090
Z	0	1241424	92878	az = 2.1294967328

INERTIAS	MOMENTS	PRODUCTS	Solve this matrix for angular accelerations (alphas)		
Ixx/Ixy	1.503E+09	-3802	1.503E+09	3.802E+03	-3.562E+07
Iyy/Ixz	1.267E+09	35620000	3.802E+03	1.267E+09	8.077E+04
Izz/Iyz	2.453E+09	-80767	-3.562E+07	8.077E+04	2.453E+09
					1.464E+08

RESULT (alpha x, y, z):

DET [A]	Alpha-x	Alpha-y	Alpha-z
4.66964E+27	-0.03489	0.54733	0.05916

110 kn Symmetrical Pull-Up, 75° Nacelle Incidence

COMPONENT	RATES (rad/s)	MOMENTS	FORCES	TRANSLATIONAL ACCELERATIONS
X	0.1570680628	819517	-9612	ax = -0.220382895
Y	0.3141361256	-1526047	7313	ay = 0.1676716725
Z	-0.226876090	-1414505	114095	az = 2.6159578127

INERTIAS	MOMENTS	PRODUCTS	Solve this matrix for angular accelerations (alphas)		
Ixx/Ixy	1.498E+09	40673	1.498E+09	-4.067E+04	-2.421E+07
Iyy/Ixz	1.263E+09	24210000	-4.067E+04	1.263E+09	-5.956E+03
Izz/Iyz	2.454E+09	5956	-2.421E+07	-5.956E+09	2.454E+09
					4.599E+09

RESULT (alpha x, y, z):

DET [A]	Alpha-x	Alpha-y	Alpha-z
4.64216E+27	22.44847	-10.69101	2.09562

Table 8. Translational and angular accelerations for eleven flight conditions. (Continued)

185kn, 3.0 G Symmetrical Pull-Up in Conversion Mode

COMPONENT	RATES (rad/s)	MOMENTS	FORCES	TRANSLATIONAL ACCELERATIONS
X	-0.052356020	18398	-21877	ax = 0.501593488
Y	0.7155322862	-2317960	-209	ay = -0.004791929
Z	0	-47945	130648	az = 2.9954832053

INERTIAS MOMENTS PRODUCTS

Ixx/Ixy	1.431E+09	168487	Solve this matrix for angular accelerations (alphas)	
Iyy/Ixz	1.220E+09	279923		
Izz/Iyz	2.475E+09	11440000		
			1.431E+09	-1.685E+05
			-1.685E+05	1.220E+09
			-2.799E+05	-1.144E+07
				2.475E+09
				2.266E+09
				-7.304E+08
				-3.106E+09

RESULT (alpha x, y, z):

DET [A]	Alpha-x	Alpha-y	Alpha-z
4.32072E+27	1.58336	-0.61023	-1.25759

289kn, 4.0 G Symmetrical Pull-Up in Airplane Mode

COMPONENT	RATES (rad/s)	MOMENTS	FORCES	TRANSLATIONAL ACCELERATIONS
X	-0.087260034	44257	-9263	ax = -0.212381061
Y	-0.174520069	4735245	-958	ay = -0.021964920
Z	0	140185	135655	az = 3.1102831595

INERTIAS MOMENTS PRODUCTS

Ixx/Ixy	1.431E+09	168487	Solve this matrix for angular accelerations (alphas)	
Iyy/Ixz	1.220E+09	279923		
Izz/Iyz	2.475E+09	11440000		
			1.431E+09	-1.685E+05
			-1.685E+05	1.220E+09
			-2.799E+05	-1.144E+07
				2.475E+09
				1.534E+08
				1.762E+09
				1.294E+09

RESULT (alpha x, y, z):

DET [A]	Alpha-x	Alpha-y	Alpha-z
4.32072E+27	0.10746	1.44888	0.52965

Table 8. Translational and angular accelerations for eleven flight conditions. (Continued)

390kn, 3.2G Left Rolling Pull-Out in Airplane Mode

COMPONENT	RATES (rad/s)	MOMENTS	FORCES	TRANSLATIONAL ACCELERATIONS
X	0.6108202443	-10342245	2912	ax = 0.0667660208
Y	0.1745200698	2818952	12167	ay = 0.2789636592
Z	0.2268760907	-3223292	139574	az = 3.2001375674

INERTIAS	MOMENTS	PRODUCTS	Solve this matrix for angular accelerations (alphas)		
Ixx/Ixy	1.431E+09	168487	1.431E+09	-1.685E+05	-2.799E+05
Iyy/Ixz	1.220E+09	279923	-1.685E+05	1.220E+09	-1.144E+07
Izz/Iyz	2.475E+09	11440000	-2.799E+05	-1.144E+07	2.475E+09
					8.076E+09

RESULT (alpha x, y, z):

DET [A]	Alpha-x	Alpha-y	Alpha-z
4.32072E+27	-16.26727	46.33314	3.47547

325kn, -1.0G Symmetrical Push-Over in Airplane Mode

COMPONENT	RATES (rad/s)	MOMENTS	FORCES	TRANSLATIONAL ACCELERATIONS
X	0.0523560209	48311	8501	ax = -0.1949100080
Y	-0.034904013	-4436588	-466	ay = -0.010684397
Z	0	-620562	-43615	az = -1

INERTIAS	MOMENTS	PRODUCTS	Solve this matrix for angular accelerations (alphas)		
Ixx/Ixy	1.431E+09	168487	1.431E+09	-1.685E+05	-2.799E+05
Iyy/Ixz	1.220E+09	279923	-1.685E+05	1.220E+09	-1.144E+07
Izz/Iyz	2.475E+09	11440000	-2.799E+05	-1.144E+07	2.475E+09
					-3.887E+08

RESULT (alpha x, y, z):

DET [A]	Alpha-x	Alpha-y	Alpha-z
4.32072E+27	0.01647	-1.40031	-0.16351

Table 8. Translational and angular accelerations for eleven flight conditions. (Concluded)

390 kn Rudder Kick in Airplane Mode

COMPONENT	RATES (rad/s)	MOMENTS	FORCES	TRANSLATIONAL ACCELERATIONS
X	0.0349040139	-1982147	12372	ax = 0.2836638771
Y	-0.034904013	-760367	-23604	ay = -0.541189957
Z	0.0174520069	-917979	44585	az = 1.0222400550

INERTIAS	MOMENTS	PRODUCTS	Solve this matrix for angular accelerations (alphas)		
Ixx/Ixy	1.431E+09	168487	1.431E+09	-1.685E+05	-2.799E+05
Iyy/Ixz	1.220E+09	279923	-1.685E+05	1.220E+09	-1.144E+07
Izz/Iyz	2.475E+09	11440000	-2.799E+05	-1.144E+07	2.475E+09
					-4.666E+08
					-4.283E+07
					-4.513E+08

RESULT (alpha x, y, z):			
DET [A]	Alpha-x	Alpha-y	Alpha-z
4.32072E+27	-0.32613	-0.03686	-0.18254

Table 9. Input data for internal loads - 2G jump take-off.

DESCRIPTION	WEIGHT	LOCATION		BL	PX	PY	EXTERNAL LOADS			
		STA	WL				PZ	CMX	CMY	CMZ
Airload	0	26	104	0	0	0	0	0	0	0
Aux Gear	277	58	80	0	0	0	0	0	0	0
Airload	0	59	104	0	0	0	0	0	0	0
Crew	635	100	106	0	0	0	0	0	0	0
Airload	0	101	140	0	0	0	0	0	0	0
Payload	2000	219	109	0	0	0	0	0	0	0
Airload	0	220	140	0	0	0	0	0	0	0
Body #1	1422	238	111	0	0	0	0	0	0	0
Airload	0	239	140	0	0	0	0	0	0	0
Fix. Equip. 1	1503	244	111	0	0	0	0	0	0	0
Airload	0	245	104	0	0	0	0	0	0	0
Payload	2000	306	106	0	0	0	0	0	0	0
Airload	0	307	140	0	0	0	0	0	0	0
Body #2	1422	315	111	0	0	0	0	0	0	0
Airload	0	316	140	0	0	0	0	0	0	0
Fix. Equip. 2	1503	340	111	0	0	0	0	0	0	0
Airload	0	341	140	0	0	0	0	0	0	0
Electrical 2	178	381	150	0	0	0	0	0	0	0
Fuselage DG	0	382	140	0	0	0	0	0	0	0
Control Wire	155	383	150	0	0	0	0	0	0	0
Front Spar	0	384	196	38	0	0	15524	0	0	0
Fitting L	50	384	196	38	0	0	0	0	0	0
Front Spar	0	384	196	-38	0	0	15524	0	0	0
Fitting R	50	384	196	-38	0	0	0	0	0	0
Rear Spar	0	431	195	38	0	0	7234	0	0	0
Fitting L	50	431	195	38	0	0	0	0	0	0
Rear Spar	0	431	195	-38	0	0	7234	0	0	0
Fitting R	50	431	195	-38	0	0	0	0	0	0
Gear L	0	460	84	60	0	0	0	0	0	0
Main Gear	377	461	84	60	0	0	0	0	0	0
Gear R	0	461	84	-60	0	0	0	0	0	0
Main Gear	377	461	84	-60	0	0	0	0	0	0
Airload	0	462	195	0	0	0	0	0	0	0
Payload	2000	480	106	0	0	0	0	0	0	0
Airload	0	481	140	0	0	0	0	0	0	0
Body #3	1422	485	111	0	0	0	0	0	0	0
Airload	0	486	140	0	0	0	0	0	0	0
Fix. Equip. 3	1503	530	111	0	0	0	0	0	0	0
Airload	0	531	111	0	0	0	0	0	0	0
Payload	2000	568	106	0	0	0	0	0	0	0
Airload	0	569	106	0	0	0	0	0	0	0
Body #4	1422	584	111	0	0	0	0	0	0	0
Airload	0	585	111	0	0	0	0	0	0	0
Fix. Equip. 4	1503	586	111	0	0	0	0	0	0	0
Airload	0	740	238	52	0	0	0	0	0	0
Horizontal Tail	110	741	238	52	0	0	0	0	0	0
Airload	0	741	238	0	0	0	0	0	0	0
Vertical Tail	388	741	238	0	0	0	0	0	0	0
Airload	0	741	238	-52	0	0	0	0	0	0
Horizontal Tail	110	742	238	-52	0	0	0	0	0	0

Table 9. Input data for internal loads - 2G jump take-off. (Continued)

	WEIGHT	LOCATION		FS	PX	EXTERNAL LOADS				
		BL	WL			PY	PZ	CMX	CMY	CMZ
Rotor L	1564	305	278	404	0	0	0	0	0	0
Thrust	0	305	278	404	-5097	0	48491	50945	0	-1E+06
Mast/Cont'l	379	305	259	404	0	0	0	0	-60000	0
Nacelle Load	0	305	259	404	0	0	0	0	0	0
Transmission	896	305	237	404	0	0	0	0	0	0
Airload	0	305	237	404	0	0	0	0	0	0
Rotor Act.	240	305	225	404	0	0	0	0	0	0
Airload	0	305	225	404	0	0	0	0	0	0
Blank	0	305	225	404	0	0	0	0	0	0
Airload	0	305	225	404	0	0	0	0	0	0
Air Ind.	40	305	223	404	0	0	0	0	0	0
Airload	0	305	223	404	0	0	0	0	0	0
Xmsn. Supp.	93	305	218	404	0	0	0	0	0	0
Airload	0	305	218	404	0	0	0	0	0	0
Bypass	13	305	212	404	0	0	0	0	0	0
Airload	0	305	212	404	0	0	0	0	0	0
Starter	52	305	209	404	0	0	0	0	0	0
Airload	0	305	209	404	0	0	0	0	0	0
Nacelle	350	304	204	404	0	0	0	0	0	0
Nacelle Drive	0	304	194	377	0	0	0	0	0	0
Pylon Supp.	214	305	194	397	0	0	0	0	0	0
Airload	0	305	194	397	0	0	0	0	0	0
Conv. Spindle	98	305	194	404	0	0	0	0	0	0
Airload	0	305	194	404	0	0	0	0	0	0
Engine	1017	305	168	408	0	0	0	0	0	0
Airload	0	305	168	408	0	0	0	0	0	0
Pivot Box	181	305	194	411	0	0	0	0	0	0
Nacelle Load	0	305	194	411	0	0	0	0	0	0
Exhaust/Eject.	36	305	168	440	0	0	0	0	0	0
Airload	0	305	168	440	0	0	0	0	0	0
Conv. Actuator	210	292	168	371	0	0	0	0	0	0
Nac/Wing	0	273	244	377	4	0	0	0	0	0
Fuel 1	1398	244	192	390	0	0	0	0	0	0
Airload	0	243	192	390	0	0	0	0	0	0
Wing #1	455	229	191	385	0	0	0	0	0	0
Wing Lift	0	229	191	385	0	0	-1625	0	0	0
Trap Fluid	65	167	189	398	0	0	0	0	0	0
Airload	0	167	189	398	0	0	0	0	0	0
Fuel System	196	167	189	398	0	0	0	0	0	0
Airload	0	166	189	398	0	0	0	0	0	0
Control Wire	155	153	174	386	0	0	0	0	0	0
Wing Air Load	0	153	174	386	0	0	0	0	0	0
Electrical 1	178	153	179	386	0	0	0	0	0	0
Airload	0	153	179	386	0	0	0	0	0	0
Wing #2	455	153	189	393	0	0	0	0	0	0
Wing Lift	0	153	189	393	0	0	-1625	0	0	0
Wing Shaft	40	153	189	420	0	0	0	0	0	0
Airload	0	153	189	420	0	0	0	0	0	0
Flap Actuator	47	153	189	435	0	0	0	0	0	0

Table 9. Input data for internal loads - 2G jump take-off. (Concluded)

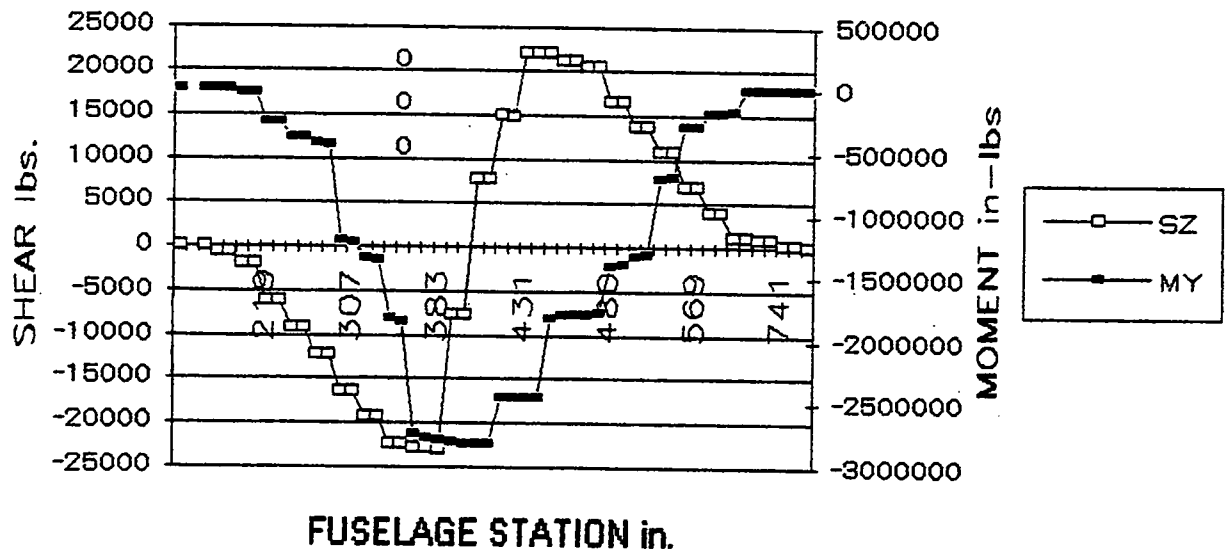
	WEIGHT	LOCATION		FS	PX	EXTERNAL LOADS				
		BL	WL			PY	PZ	CMX	CMY	CMZ
Fuel 2	1398	91	186	406	0	0	0	0	0	0
Wing Lift	0	76	186	401	0	0	-1625	0	0	0
Wing #3	455	76	186	401	0	0	0	0	0	0
Wing/Body	0	57	185	409	55	0	0	0	0	0
Blank	0	57	185	409	0	0	0	0	0	0
Front Spar	0	38	196	384	0	0	-15524	0	0	0
Front Spar FTO	50	37.9	196	384	0	0	0	0	0	0
Rear Spar	0	37.8	195	431	0	0	-7234	0	0	0
Rear Spar FTO	50	37.7	195	431	0	0	0	0	0	0
Wing Cl.	0	0	196	405	0	0	0	0	0	0

Table 10. Output data for internal loads - 2G jump take-off.

STA	FUSELAGE SHEARS			MOMENTS		
	SX	SY	SZ	MX	MY	MZ
26	0	0	0	0	0	0
58	4	-1	-602	48	-129	0
59	4	-1	-602	48	-731	-1
100	6	2	-1969	28	-25415	-63
101	6	2	-1969	28	-27385	-61
219	12	5	-6172	3	-259822	138
220	12	5	-6172	3	-265995	143
238	13	11	-9149	-5	-377101	242
239	13	11	-9149	-5	-386250	253
244	14	16	-12291	-13	-431996	306
245	14	16	-12291	-13	-444287	322
306	19	15	-16417	-9	-1194072	1288
307	19	15	-16417	-9	-1210489	1303
315	20	17	-19346	-12	-1341829	1424
316	20	17	-19346	-12	-1361175	1442
340	21	19	-22424	-15	-1825469	1861
341	21	19	-22424	-15	-1847893	1880
381	18	22	-22785	99	-2744962	2637
382	18	22	-22785	99	-2767747	2659
383	16	25	-23100	198	-2790628	2681
384	16	25	-7575	-589731	-2813728	2705
384	14	26	-7677	-589544	-2813881	2707
384	14	26	7848	385	-2813881	2707
384	12	28	7746	573	-2814035	2709
431	12	28	14980	-274321	-2449966	4041
431	10	30	14880	-274142	-2450115	4042
431	10	30	22114	751	-2450115	4042
431	9	32	22013	930	-2450265	4044
460	9	32	22013	930	-1811876	4969
461	13	27	21261	1679	-1789998	5036
461	13	27	21261	1679	-1789998	5036
461	18	21	20509	2428	-1790133	5072
462	18	21	20509	2428	-1769624	5093
480	24	12	16536	2491	-1400495	5476
481	24	12	16536	2491	-1383959	5488
485	25	8	13714	2498	-1317816	5534
486	25	8	13714	2498	-1304102	5542
530	26	2	10762	2507	-700670	5878
531	26	2	10762	2507	-689908	5879
568	32	-13	6866	2600	-291763	5942
569	32	-13	6866	2600	-284896	5930
584	33	-20	4106	2612	-181906	5741
585	33	-20	4106	2612	-177800	5721
586	34	-28	1191	2625	-173695	5701
740	34	-28	1191	2625	9680	1346

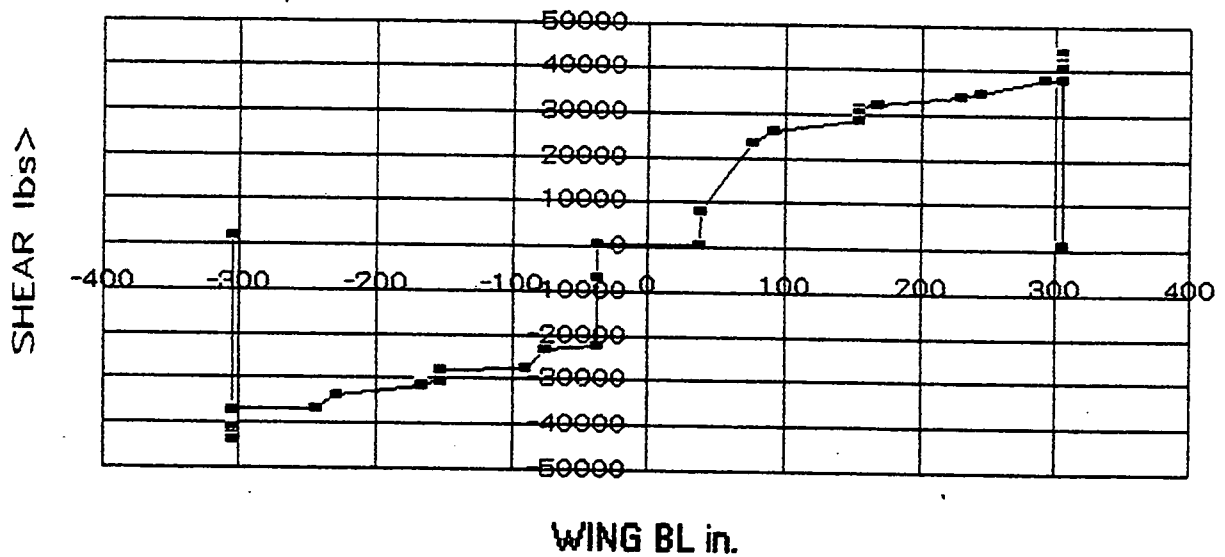
Table 10. Output data for internal loads - 2G jump take-off. (Concluded)

STA	FUSELAGE SHEARS			MOMENTS		
	SX	SY	SZ	MX	MY	MZ
741	28	-23	985	3398	10108	1325
741	28	-23	985	3398	10108	1325
741	6	-5	259	5662	7419	1325
741	6	-5	259	5662	7419	1325
742	0	0	53	6434	6916	1328
WING SHEAR AND MOMENTS						
BL	SZ	SY	SX	MY	MZ	MX
305	44256	-2207	-7472	-155191	-975444	120929
305	38177	-1952	-7174	-79855	-970987	112686
292	37777	-1940	-7150	-730731	-1038036	688014
244	35099	-1847	-7004	-302964	-1182137	2494918
229	34223	-1817	-6957	-182953	-1229593	3020586
167	34274	-1751	-6865	274500	-1434541	5043018
167	32093	-1738	-6845	278460	-1434406	5042623
153	31790	-1729	-6827	377555	-1481179	5492279
153	31441	-1718	-6807	376489	-1481210	5492443
153	30552	-1687	-6758	379995	-1481089	5492122
153	28852	-1623	-6669	388863	-1480761	5491194
153	28761	-1620	-6663	393094	-1480615	5490754
91	25999	-1527	-6507	821810	-1697928	7275144
76	23474	-1435	-6371	917208	-1753823	7641545
76	23477	-1430	-6317	917966	-1753794	7641465
38	7884	-839	-5499	856658	-1754000	8760000
38	7884	-839	-5499	856658	-1754000	8760000
76	23477	-1430	-6317	917966	-1753794	7641465
76	23474	-1435	-6371	917208	-1753823	7641545
91	25999	-1527	-6507	821810	-1697928	7275144
153	28761	-1620	-6663	393094	-1480615	5490754
153	28852	-1623	-6669	388863	-1480761	5491194
153	30552	-1687	-6758	379995	-1481089	5492122
153	31441	-1718	-6807	376489	-1481210	5492443
153	31790	-1729	-6827	377555	-1481179	5492279
167	32093	-1738	-6845	278460	-1434406	5042623
167	34274	-1751	-6865	274500	-1434541	5043018
229	34223	-1817	-6957	-182953	-1229593	3020586
244	35099	-1847	-7004	-302964	-1182137	2494918
292	37777	-1940	-7150	-730731	-1038036	688014
305	38177	-1952	-7174	-79855	-970987	112686
305	44256	-2207	-7472	-155191	-975444	120929



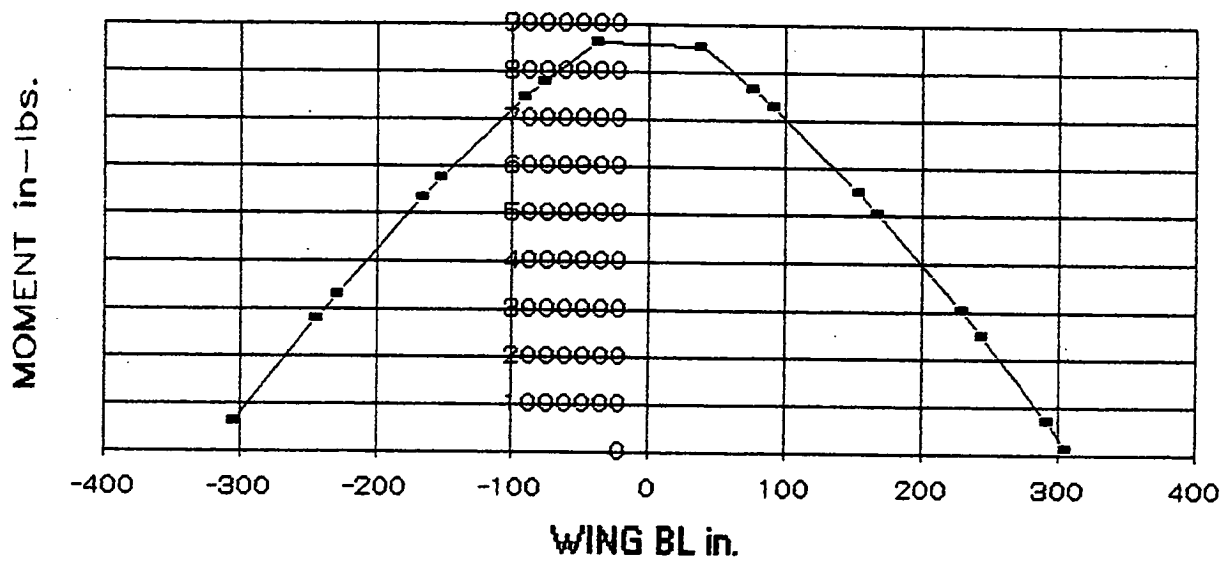
2-E932

Figure 11. Fuselage vertical shear and moment diagrams - 2G.



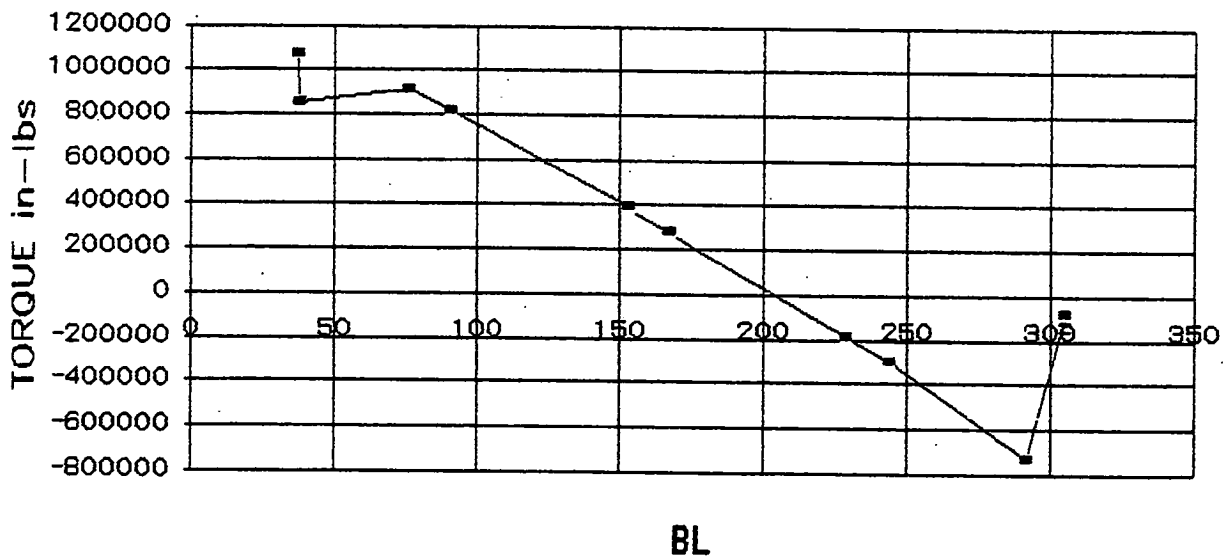
2-E933

Figure 12. Wing shear - 2G.



2-E934

Figure 13. Wing moment - 2G.



2-E935

Figure 14. Wing torque - 2G.

Table 11. Input data for internal loads - 4G symmetrical pull up.

DESCRIPTION	WEIGHT	LOCATION		BL	PX	PY	EXTERNAL LOADS			
		STA	WL				PZ	CMX	CMY	CMZ
Fuselage										
Airload	0	26	104	0	0	0	0	0	0	0
Aux Gear	277	58	80	0	0	0	0	0	0	0
Airload	0	59	104	0	0	0	0	0	0	0
Crew	635	100	106	0	0	0	0	0	0	0
Airload	0	101	140	0	0	0	0	0	0	0
Payload	2000	219	106	0	0	0	0	0	0	0
Airload	0	220	140	0	0	0	0	0	0	0
Body #1	1422	238	111	0	0	0	0	0	0	0
Airload	0	239	140	0	0	0	0	0	0	0
Fix. Equip. 1	1503	244	111	0	0	0	0	0	0	0
Airload	0	245	104	0	0	0	0	0	0	0
Payload	2000	306	106	0	0	0	0	0	0	0
Airload	0	307	140	0	0	0	0	0	0	0
Body #2	1422	315	111	0	0	0	0	0	0	0
Airload	0	316	140	0	0	0	0	0	0	0
Fix. Equip. 2	1503	340	111	0	0	0	0	0	0	0
Airload	0	341	140	0	0	0	0	0	0	0
Electrical 2	178	381	150	0	0	0	0	0	0	0
Fuselage DG	0	382	140	0	-17	-113	16085	-3799	1670202	35682
Control Wire	155	383	150	0	0	0	0	0	0	0
Front Spar	0	384	196	38	0	0	11729	0	0	0
Fitting L	50	384	196	38	0	0	0	0	0	0
Front Spar	0	384	196	-38	0	0	11729	0	0	0
Fitting R	50	384	196	-38	0	0	0	0	0	0
Rear Spar	0	431	195	38	0	0	10755	0	0	0
Fitting L	50	431	195	38	0	0	0	0	0	0
Rear Spar	0	431	195	-38	0	0	10755	0	0	0
Fitting R	50	431	195	-38	0	0	0	0	0	0
Gear L	0	460	84	60	0	0	0	0	0	0
Main Gear	377	461	84	60	0	0	0	0	0	0
Gear R	0	461	84	-60	0	0	0	0	0	0
Main Gear	377	461	84	-60	0	0	0	0	0	0
Airload	0	462	195	0	0	0	0	0	0	0
Payload	2000	480	106	0	0	0	0	0	0	0
Airload	0	481	140	0	0	0	0	0	0	0
Body #3	1422	485	111	0	0	0	0	0	0	0
Airload	0	486	140	0	0	0	0	0	0	0
Fix. Equip. 3	1503	530	111	0	0	0	0	0	0	0
Airload	0	531	111	0	0	0	0	0	0	0
Payload	2000	568	106	0	0	0	0	0	0	0
Airload	0	569	106	0	0	0	0	0	0	0
Body #4	1422	584	111	0	0	0	0	0	0	0
Airload	0	585	111	0	0	0	0	0	0	0
Fix. Equip. 4	1503	586	111	0	0	0	0	0	0	0
Airload	0	740	238	52	0	0	0	0	0	0
Horizontal Tail	110	741	238	52	-789	2	4880.5	-2E+05	4	2
Airload	0	741	238	0	0	0	0	0	0	0
Vertical Tail	388	741	238	0	0	0	0	0	0	0
Airload	0	741	238	-52	-789	2	4880.5	-2E+05	4	2

Table 11. Input data for internal loads - 4G symmetrical pull up. (Continued)

	WEIGHT	LOCATION		FS	PX	EXTERNAL LOADS				
		BL	WL			PY	PZ	CMX	CMY	CMZ
Horizontal Tail	110	742	238	-52	0	0	0	0	0	0
Rotor L	1564	305	194	320	0	0	0	0	0	0
Thrust	0	305	194	320	-2177	48	1152	293292	0	0
Mast/Cont1	379	305	194	339	0	0	0	0	174110	-63054
Nacelle Load	0	305	194	339	532	-203	5648	-2217	247599	3674
Transmission	896	305	194	361	0	0	0	0	0	0
Airload	0	305	194	361	0	0	0	0	0	0
Rotor Act.	240	305	194	373	0	0	0	0	0	0
Airload	0	305	194	373	0	0	0	0	0	0
Blank	0	305	194	373	0	0	0	0	0	0
Airload	0	305	194	373	0	0	0	0	0	0
Air Ind.	40	305	194	375	0	0	0	0	0	0
Airload	0	305	194	375	0	0	0	0	0	0
Xmsn. Supp.	93	305	194	380	0	0	0	0	0	0
Airload	0	305	194	380	0	0	0	0	0	0
Bypass	13	305	194	386	0	0	0	0	0	0
Airload	0	305	194	386	0	0	0	0	0	0
Starter	52	305	194	389	0	0	0	0	0	0
Airload	0	305	194	389	0	0	0	0	0	0
Nacelle	350	304	194	394	0	0	0	0	0	0
Nacelle Drive	0	304	194	377	0	0	0	0	0	0
Pylon Supp.	214	305	194	397	0	0	0	0	0	0
Airload	0	305	194	397	0	0	0	0	0	0
Conv. Spindle	98	305	194	404	0	0	0	0	0	0
Airload	0	305	194	404	0	0	0	0	0	0
Engine	1017	305	168	408	0	0	0	0	0	0
Airload	0	305	168	408	0	0	0	0	0	0
Pivot Box	181	305	194	411	0	0	0	0	0	0
Nacelle Load	0	305	194	411	0	0	0	0	0	0
Exhaust/Eject.	36	305	168	440	0	0	0	0	0	0
Airload	0	305	168	440	0	0	0	0	0	0
Conv. Actuator	210	292	168	371	0	0	0	0	0	0
Nac/Wing	0	273	244	377	4	0	0	0	0	0
Fuel 1	1398	244	192	390	0	0	0	0	0	0
Airload	0	243	192	390	0	0	0	0	0	0
Wing #1	455	229	191	385	0	0	0	0	0	0
Wing Lift	0	229	191	385	-987	0	16498	1	-247467	0
Trap Fluid	65	167	189	398	0	0	0	0	0	0
Airload	0	167	189	398	0	0	0	0	0	0
Fuel System	196	167	189	398	0	0	0	0	0	0
Airload	0	166	189	398	0	0	0	0	0	0
Control Wire	155	153	174	386	0	0	0	0	0	0
Wing Air Load	0	153	174	386	0	0	0	0	0	0
Electrical 1	178	153	179	386	0	0	0	0	0	0
Airload	0	153	179	386	0	0	0	0	0	0
Wing #2	455	153	189	393	0	0	0	0	0	0
Wing Lift	0	153	189	393	-987	0	16498	1	-247467	0
Wing Shaft	40	153	189	420	0	0	0	0	0	0
Airload	0	153	189	420	0	0	0	0	0	0
Flap Actuator	47	153	189	435	0	0	0	0	0	0

Table 11. Input data for internal loads - 4G symmetrical pull up. (Concluded)

	WEIGHT	LOCATION		FS	PX	EXTERNAL LOADS				
		BL	WL			PY	PZ	CMX	CMY	CMZ
Airload	0	153	189	435	0	0	0	0	0	0
Fuel 2	1398	91	186	406	0	0	0	0	0	0
Wing Lift	0	76	186	401	-987	0	16498	1	-247467	0
Wing #3	455	76	186	397	0	0	0	0	0	0
Wing/Body	0	57	185	397	55	0	0	0	0	0
Blank	0	57	185	397	0	0	0	0	0	0
Front Spar	0	38	196	391	0	0	-11729	0	0	0
Front Spar FTG	50	38	196	391	0	0	0	0	0	0
Rear Spar	0	38	195	434	0	0	-10755	0	0	0
Rear Spar FTG	50	38	195	434	0	0	0	0	0	0
Wing Cl.	0	0	196	408	0	0	0	0	0	0

Table 12. Output data for internal loads - 289kn, 4G symmetrical pull up.

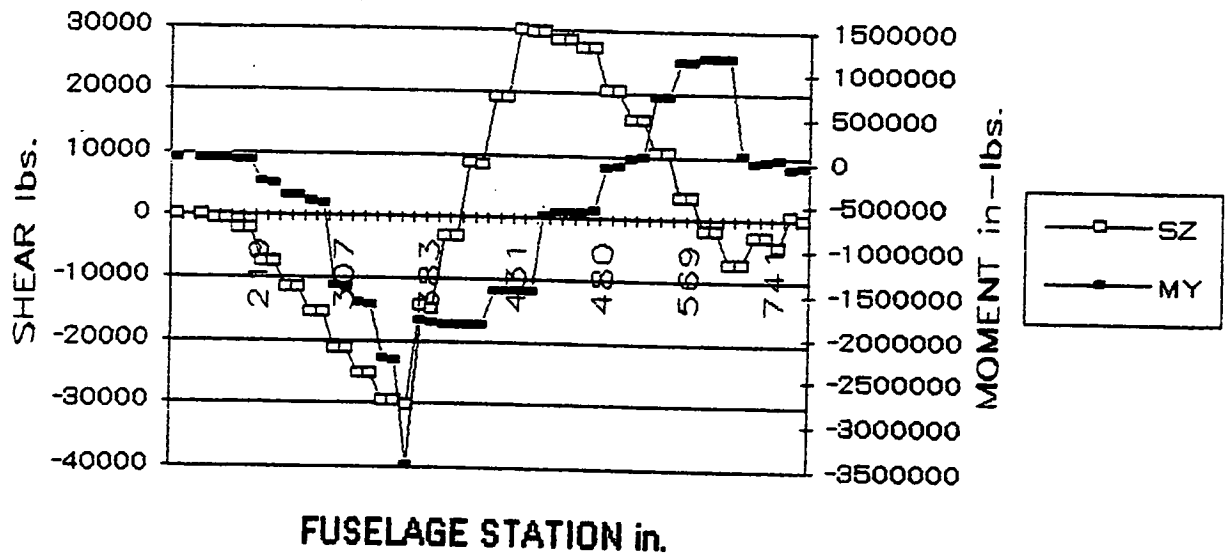
STA	FUSELAGE SHEARS			MOMENTS		
	SX	SY	SZ	MX	MY	MZ
26	0	0	0	0	0	0
58	-7	-109	-621	3558	219	0
59	-7	-109	-621	3558	-402	-109
100	21	-350	-2115	5133	-26060	-4591
101	21	-350	-2115	5133	-28175	-4940
219	107	-786	-7436	7992	-278327	-46193
220	107	-786	-7436	7992	-285764	-46978
238	186	-1071	-11290	8435	-419741	-61123
239	186	-1071	-11290	8435	-431031	-62194
244	270	-1359	-15386	8884	-487610	-67547
245	270	-1359	-15386	8884	-502996	-68906
306	356	-1561	-21158	10207	-1442097	-151836
307	356	-1561	-21158	10207	-1463255	-153397
315	436	-1699	-25295	10420	-1632641	-165888
316	436	-1699	-25295	10420	-1657936	-167586
340	520	-1793	-29765	10567	-2265142	-208353
341	520	-1793	-29765	10567	-2294907	-210146
381	548	-1805	-30313	10112	-3484453	-281871
382	531	-1918	-14228	3212	-1845031	-247994
383	555	-1928	-14706	2831	-1858347	-249912
384	555	-1928	-2977	-442879	-1873054	-251841
384	569	-1935	-3132	-443558	-1871902	-251938
384	569	-1935	8598	2153	-1871902	-251938
384	583	-1942	8443	1474	-1870749	-252035
431	583	-1942	19198	-407208	-1473915	-343309
431	597	-1946	19038	-407612	-1472787	-343406
431	597	-1946	29792	1070	-1472787	-343406
431	610	-1949	29632	665	-1471659	-343504
460	610	-1949	29632	665	-612335	-400027
461	605	-1896	28392	-2974	-582553	-403805
461	605	-1896	28392	-2974	-582553	-403805
461	600	-1842	27153	-6613	-582402	-405633
462	600	-1842	27153	-6613	-555249	-407475
480	686	-1575	20480	-8363	-67058	-440630
481	686	-1575	20480	-8363	-46578	-442205
485	765	-1387	15716	-8656	35216	-448505
486	765	-1387	15716	-8656	50932	-449891
530	850	-1096	10506	-9107	742319	-510901
531	850	-1096	10506	-9107	752825	-511998
568	936	-592	3377	-12411	1141001	-552564
569	936	-592	3377	-12411	1144378	-553156
584	1015	-214	-1751	-12999	1194909	-562041
585	1015	-214	-1751	-12999	1193158	-562255
586	1099	189	-7179	-13626	1191277	-562469
740	1099	189	-7179	-13626	85735	-533316

Table 12. Output data for internal loads - 289kn, 4G symmetrical pull up. (Continued)

STA	FUSELAGE SHEARS			MOMENTS		
	SX	SY	SZ	MX	MY	MZ
741	353	222	-2740	-439770	-15104	-574554
741	600	-153	-2740	-486812	15881	-574554
741	749	-44	-4297	-473188	34620	-574554
741	-40	-42	584	-395160	-64353	-533524
742	2	-11	142	-391741	-58457	-533966
WING SHEAR AND MOMENTS						
BL	SZ	SY	SX	MY	MZ	MX
305	-4514	707	-2735	-170564	-128782	302158
305	-2011	499	-1888	275298	-98350	254620
305	-2862	543	-1729	256394	-99191	256532
305	-2862	543	-1729	256394	-99191	256532
305	-3005	551	-1703	253536	-99316	256822
305	-3336	569	-1641	248579	-99524	257324
305	-3383	571	-1633	248168	-99540	257366
305	-3570	582	-1599	247081	-99582	257479
305	-4830	658	-1368	246008	-99623	257610
305	-5603	705	-1226	247624	-99567	257464
305	-5958	728	-1161	250777	-99465	257158
305	-9660	1001	-561	287752	-97823	252529
305	-10283	191	1097	280348	-117851	270500
305	-10416	202	1118	285575	-117693	269989
292	-11157	247	1238	461545	-115187	114266
244	-16053	528	2038	398961	-111837	-421060
229	-17631	615	2286	354249	-107215	-660564
167	-1440	-99	472	26862	-99603	-720764
167	-2108	-60	560	32961	-99374	-721402
153	-2629	-29	621	26982	-94743	-751202
153	-3226	6	693	24242	-94870	-751036
153	-4762	92	889	28769	-94690	-751544
153	11512	-625	-937	-291275	-106904	-717862
153	11349	-614	-917	-284481	-106755	-718540
91	6712	-333	-448	-76646	-84771	-29596
76	21636	-976	-2148	-349259	-94525	349906
76	21638	-970	-2094	-348501	-94496	349826
38	9762	-600	-1637	-281325	-87986	1175319
38	-1131	-183	-1060	75947	-74672	1138664
-38	-1297	-172	-1045	75776	-164199	1062522
-38	-12177	234	-473	426189	-151218	1024339
-38	-23882	677	141	309298	-155609	1037812
-76	-25368	834	399	295495	-245593	127867
-91	-14447	582	706	116120	-264701	-238
-153	-15070	629	781	122598	-310847	-901822
-153	-15606	668	844	137290	-310324	-903331
-153	-1568	231	839	-171601	-322068	-870869
-153	-1703	238	857	-172145	-322091	-870819
-153	-1862	247	878	-172785	-322118	-870761
-167	-2533	286	970	-171119	-312114	-898419

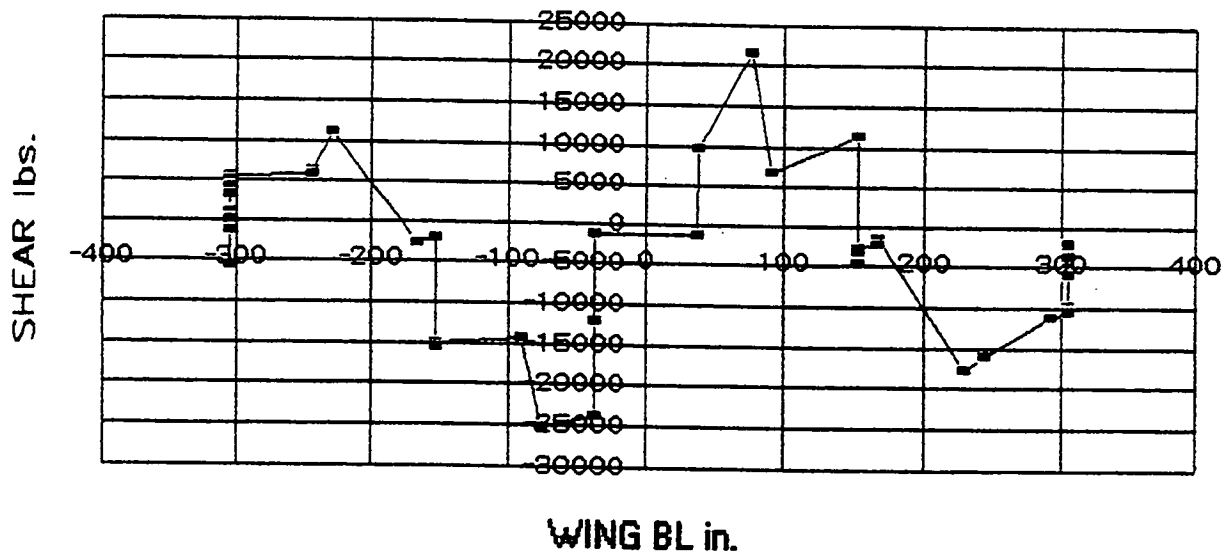
Table 12. Output data for internal loads - 289kn, 4G symmetrical pull up. (Concluded)

BL	WING SHEAR AND MOMENTS					
	SZ	SY	SX	MY	MZ	MX
-167	-2756	299	1001	-169098	-312038	-898630
-229	11241	-138	1048	-366094	-188772	-88049
-244	6320	146	1867	-327272	-154131	74663
-244	5758	160	1831	-331306	-154340	75016
-305	5623	172	1853	-240280	-4774	404301
-305	4960	215	1975	-230023	-4467	403295
-305	1240	492	2593	-193415	-2839	398705
-305	883	516	2656	-190686	-2737	398422
-305	107	563	2801	-189102	-2682	398280
-305	-1161	644	3025	-191621	-2779	398446
-305	4252	184	2258	66838	11568	371634
-305	4206	186	2266	66139	11539	371705
-305	4134	-252	1803	68825	12177	372378
-305	3991	-244	1830	65944	12051	372669
-305	3135	-199	1993	46899	11205	374597
-305	-61	-31	2601	-24204	8047	381792
-305	-1362	12	2858	32352	76499	371595
-305	-5587	297	5895	-232043	52899	124871
-305	-5587	297	5895	-232043	52899	124871



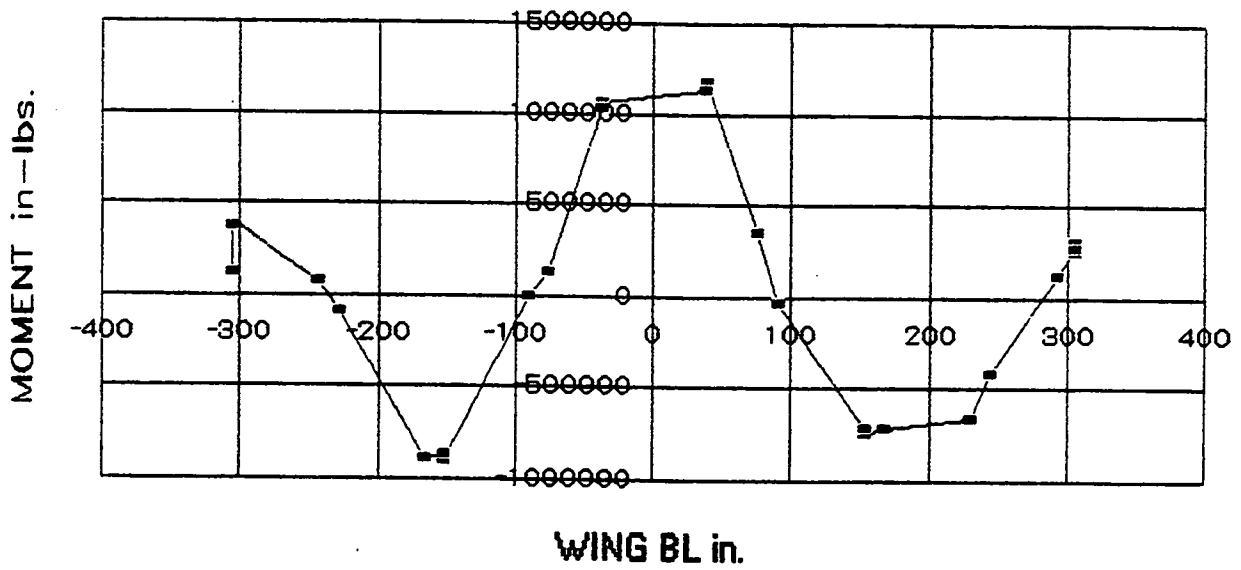
2-E974

Figure 15. Fuselage vertical shear and moment diagrams 4G.



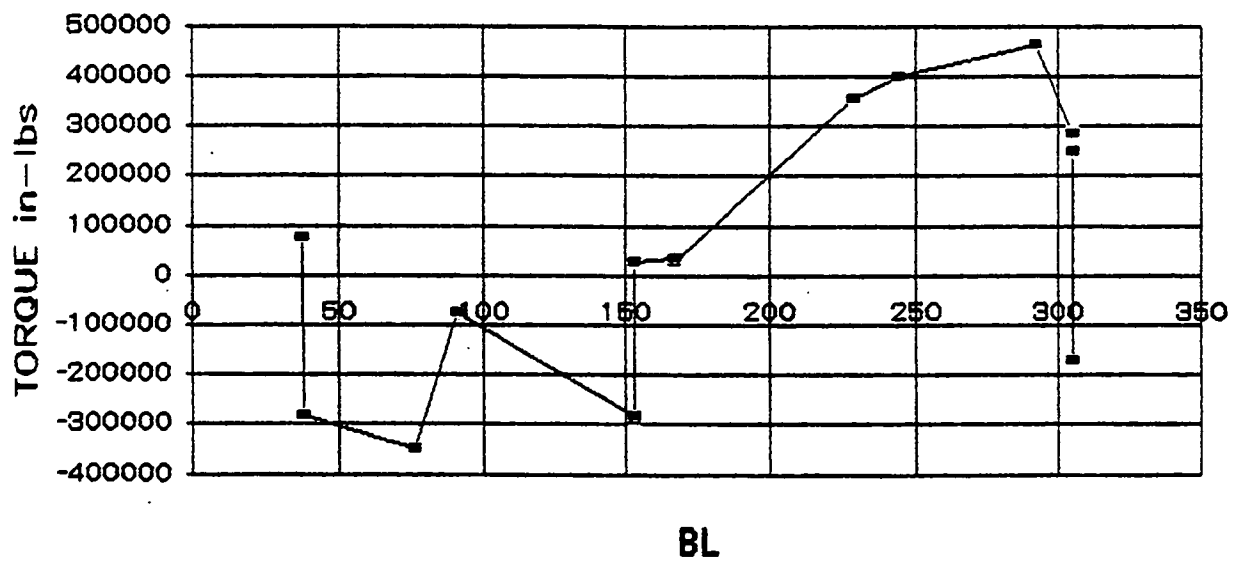
2-E975

Figure 16. Wing shear 4G.



2-E976

Figure 17. Wing moment 4G.



2-E977

Figure 18. Wing torque 4G.

Table 13. Input data for internal loads - 110kn, 75° tilt

DESCRIPTION	WEIGHT	LOCATION		BL	PX	PY	EXTERNAL LOADS			
		STA	WL				PZ	CMX	CMY	CMZ
Fuselage										
Airload	0	26	104	0	0	0	0	0	0	0
Aux Gear	277	58	80	0	0	0	0	0	0	0
Airload	0	59	104	0	0	0	0	0	0	0
Crew	635	100	106	0	0	0	0	0	0	0
Airload	0	101	140	0	0	0	0	0	0	0
Payload	2000	219	106	0	0	0	0	0	0	0
Airload	0	220	140	0	0	0	0	0	0	0
Body #1	1422	238	111	0	0	0	0	0	0	0
Airload	0	239	140	0	0	0	0	0	0	0
Fix. Equip. 1	1503	244	111	0	0	0	0	0	0	0
Airload	0	245	104	0	0	0	0	0	0	0
Payload	2000	306	106	0	0	0	0	0	0	0
Airload	0	307	140	0	0	0	0	0	0	0
Body #2	1422	315	111	0	0	0	0	0	0	0
Airload	0	316	140	0	0	0	0	0	0	0
Fix. Equip. 2	1503	340	111	0	0	0	0	0	0	0
Airload	0	341	140	0	0	0	0	0	0	0
Electrical 2	178	381	150	0	0	0	0	0	0	0
Fuselage DG	0	382	140	0	-124	530	2720	40593	157558	-92602
Control Wire	155	383	150	0	0	0	0	0	0	0
Front Spar	0	384	196	38	0	0	30445	0	0	0
Fitting L	50	384	196	38	0	0	0	0	0	0
Front Spar	0	384	196	-38	0	0	30445	0	0	0
Fitting R	50	384	196	-38	0	0	0	0	0	0
Rear Spar	0	431	195	38	0	0	-2602	0	0	0
Fitting L	50	431	195	38	0	0	0	0	0	0
Rear Spar	0	431	195	-38	0	0	-2602	0	0	0
Fitting R	50	431	195	-38	0	0	0	0	0	0
Gear L	0	460	84	60	0	0	0	0	0	0
Main Gear	377	461	84	60	0	0	0	0	0	0
Gear R	0	461	84	-60	0	0	0	0	0	0
Main Gear	377	461	84	-60	0	0	0	0	0	0
Airload	0	462	195	0	0	0	0	0	0	0
Payload	2000	480	106	0	0	0	0	0	0	0
Airload	0	481	140	0	0	0	0	0	0	0
Body #3	1422	485	111	0	0	0	0	0	0	0
Airload	0	486	140	0	0	0	0	0	0	0
Fix. Equip. 3	1503	530	111	0	0	0	0	0	0	0
Airload	0	531	111	0	0	0	0	0	0	0
Payload	2000	568	106	0	0	0	0	0	0	0
Airload	0	569	106	0	0	0	0	0	0	0
Body #4	1422	584	111	0	0	0	0	0	0	0
Airload	0	585	111	0	0	0	0	0	0	0
Fix. Equip. 4	1503	586	111	0	0	0	0	0	0	0
Airload	0	740	238	52	0	0	0	0	0	0
Horizontal Tail	110	741	238	52	-106	21	483.5	-9412	2	3
Airload	0	741	238	0	-28	1495	0	0	0	0
Horizontal Tail	110	742	238	-52	0	0	0	0	0	0
Vertical Tail	388	741	238	0	0	0	0	0	0	0

Table 13. Input data for internal loads - 110kn, 75° tilt. (Continued)

	WEIGHT	LOCATION		FS	PX	EXTERNAL LOADS				
		BL	WL			PY	PZ	CMX	CMY	CMZ
Airload	0	741	238	-52	-106	21	483.5	-9412	2	3
Rotor L	1564	305	275	382	0	0	0	0	0	0
Thrust	0	305	275	382	-2667	403	44175	273692	-44595	-1000000
Mast/Cont'l	379	305	257	387	0	0	0	-91031	82987	-24392
Nacelle Load	0	305	257	387	1850	1195	-290	12439	74620	20267
Transmission	896	305	236	393	0	0	0	0	0	0
Airload	0	305	236	393	0	0	0	0	0	0
Rotor Act.	240	305	224	396	0	0	0	0	0	0
Airload	0	305	224	396	0	0	0	0	0	0
Blank	0	305	224	396	0	0	0	0	0	0
Airload	0	305	224	396	0	0	0	0	0	0
Air Ind.	40	305	222	396	0	0	0	0	0	0
Airload	0	305	222	396	0	0	0	0	0	0
Xmsn. Supp.	93	305	217	398	0	0	0	0	0	0
Airload	0	305	217	398	0	0	0	0	0	0
Bypass	13	305	211	399	0	0	0	0	0	0
Airload	0	305	211	399	0	0	0	0	0	0
Starter	52	305	208	400	0	0	0	0	0	0
Airload	0	305	208	400	0	0	0	0	0	0
Nacelle	350	304	204	401	0	0	0	0	0	0
Nacelle Drive	0	304	194	377	0	0	0	0	0	0
Pylon Supp.	214	305	194	397	0	0	0	0	0	0
Airload	0	305	194	397	0	0	0	0	0	0
Conv. Spindle	98	305	194	404	0	0	0	0	0	0
Airload	0	305	194	404	0	0	0	0	0	0
Engine	1017	305	168	408	0	0	0	0	0	0
Airload	0	305	168	408	0	0	0	0	0	0
Pivot Box	181	305	194	411	0	0	0	0	0	0
Nacelle Load	0	305	194	411	0	0	0	0	0	0
Exhaust/Eject.	36	305	168	440	0	0	0	0	0	0
Airload	0	305	168	440	0	0	0	0	0	0
Conv. Actuator	210	292	168	371	0	0	0	0	0	0
Nac/Wing	0	273	244	377	4	0	0	0	0	0
Fuel 1	1398	244	192	390	0	0	0	0	0	0
Airload	0	243	192	390	0	0	0	0	0	0
Wing #1	455	229	191	385	0	0	0	0	0	0
Wing Lift	0	229	191	385	-958	0	3859	0	-30482	0
Trap Fluid	65	167	189	398	0	0	0	0	0	0
Airload	0	167	189	398	0	0	0	0	0	0
Fuel System	196	167	189	398	0	0	0	0	0	0
Airload	0	166	189	398	0	0	0	0	0	0
Control Wire	155	153	174	386	0	0	0	0	0	0
Wing Air Load	0	153	174	386	0	0	0	0	0	0
Electrical 1	178	153	179	386	0	0	0	0	0	0
Airload	0	153	179	386	0	0	0	0	0	0
Wing #2	455	153	189	393	0	0	0	0	0	0
Wing Lift	0	153	189	393	-958	0	3859	0	-30482	0
Wing Shaft	40	153	189	420	0	0	0	0	0	0
Airload	0	153	189	420	0	0	0	0	0	0
Flap Actuator	47	153	189	435	0	0	0	0	0	0

Table 13. Input data for internal loads - 110kn, 75° tilt. (Concluded)

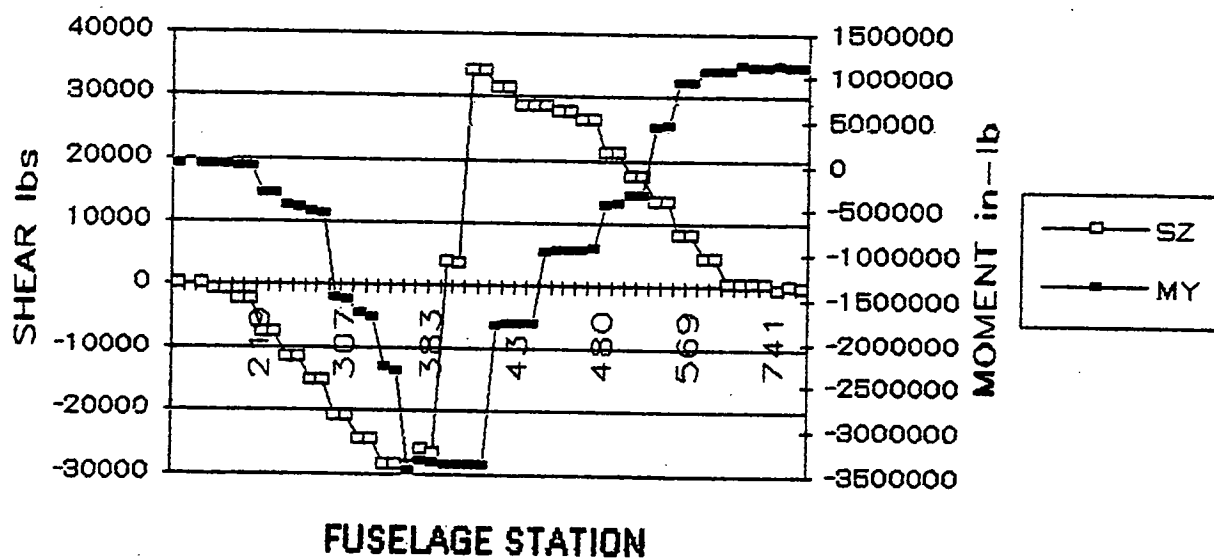
	WEIGHT	LOCATION		FS	PX	EXTERNAL LOADS				
		BL	WL			PY	PZ	CMX	CMY	CMZ
Airload	0	153	189	435	0	0	0	0	0	0
Fuel 2	1398	91	186	406	0	0	0	0	0	0
Wing Lift	0	76	186	401	-958	0	3859	0	-30482	0
Wing #3	455	76	186	401	0	0	0	0	0	0
Wing/Body	0	57	185	409	55	0	0	0	0	0
Blank	0	57	185	409	0	0	0	0	0	0
Front Spar	0	38	196	384	0	0	-30445	0	0	0
Front Spar FTG	50	38	196	384	0	0	0	0	0	0
Rear Spar	0	38	195	431	0	0	2602	0	0	0
Rear Spar FTG	50	38	195	431	0	0	0	0	0	0
Wing Cl.	0	0	196	405	0	0	0	0	0	0

Table 14. Output data for internal loads - 110kn, 75° tilt.

STA	FUSELAGE SHEARS			MOMENTS		
	SX	SY	SZ	MX	MY	MZ
26	0	0	0	0	0	0
58	61	-28	-734	902	-1984	0
59	61	-28	-734	902	-2718	-28
100	201	-91	-2417	1318	-33730	-1163
101	201	-91	-2417	1318	-36146	-1255
219	641	-291	-7717	2629	-324213	-12016
220	641	-291	-7717	2629	-331929	-12307
238	953	-433	-11485	2850	-471318	-17549
239	953	-433	-11485	2850	-482803	-17982
244	1284	-584	-15468	3083	-540743	-20149
245	1284	-584	-15468	3083	-556211	-20733
306	1724	-784	-20768	4394	-1502646	-56339
307	1724	-784	-20768	4394	-1523414	-57123
315	2037	-926	-24536	4615	-1690044	-63392
316	2037	-926	-24536	4615	-1714581	-64318
340	2368	-1076	-28519	4849	-2303967	-86540
341	2368	-1076	-28519	4849	-2332486	-87616
381	2407	-1094	-28991	4182	-3471792	-130664
382	2283	-564	-26271	59322	-3346628	-224360
383	2317	-580	-26682	58741	-3371622	-224924
384	2317	-580	3763	-1098151	-3398304	-225503
384	2328	-585	3630	-1098568	-3397386	-225503
384	2328	-585	34075	58324	-3397386	-225503
384	2339	-590	33942	57907	-3396468	-225503
431	2339	-590	31341	156775	-1801179	-253210
431	2350	-595	31208	156362	-1800272	-253210
431	2350	-595	28606	57495	-1800272	-253210
431	2361	-600	28474	57082	-1799365	-253210
460	2361	-600	28474	57082	-973626	-270595
461	2444	-637	27475	58159	-947521	-271195
461	2444	-637	27475	58159	-947521	-271195
461	2527	-675	26476	59235	-949889	-271195
462	2527	-675	26476	59235	-923414	-271870
480	2967	-875	21176	60546	-449736	-284018
481	2967	-875	21176	60546	-428560	-284893
485	3280	-1017	17407	60767	-344344	-288392
486	3280	-1017	17407	60767	-326937	-289410
530	3610	-1167	13424	61001	438473	-334162
531	3610	-1167	13424	61001	451897	-335329
568	4050	-1367	8124	62312	945716	-378523
569	4050	-1367	8124	62312	953841	-379891
584	4363	-1510	4356	62533	1075220	-400402
585	4363	-1510	4356	62533	1079576	-401911
586	4694	-1660	373	62766	1083419	-403421
740	4694	-1660	373	62766	1140884	-659045

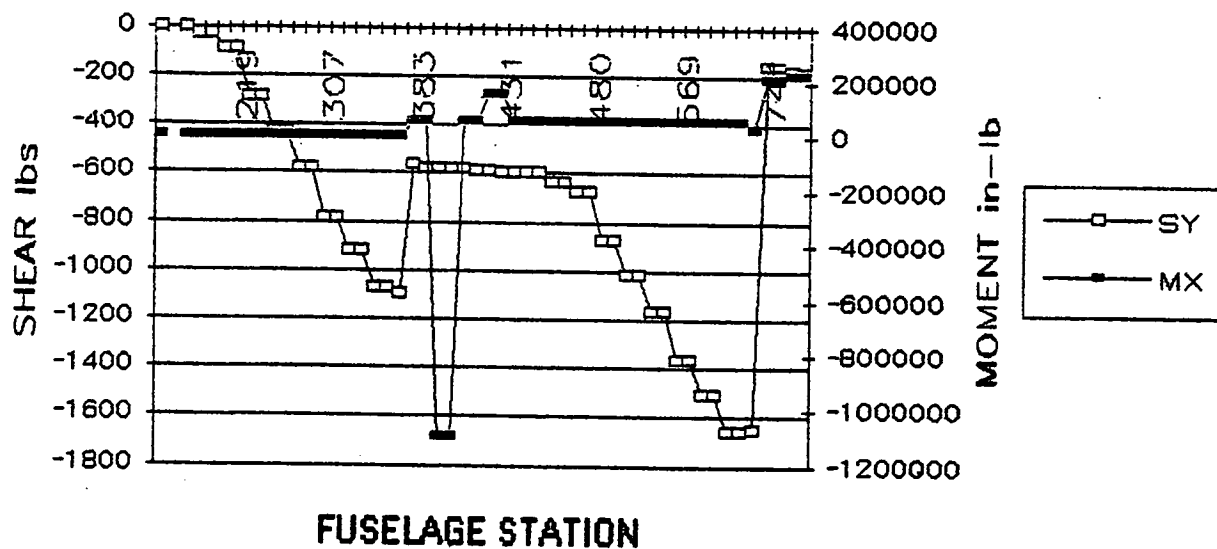
Table 14. Output data for internal loads - 110kn, 75° tilt. (Concluded)

STA	FUSELAGE SHEARS			MOMENTS		
	SX	SY	SZ	MX	MY	MZ
741	4612	-1650	565	29467	1131060	-666188
741	4584	-155	565	217009	1127548	-666188
741	4670	-194	-463	212141	1138256	-666188
741	4564	-173	20	230506	1125023	-660699
742	4589	-184	-271	229126	1128079	-660872
WING SHEAR AND MOMENTS						
BL	SZ	SY	SX	MY	MZ	MX
305	37287	2426	2492	1070966	-986730	297915
305	28110	303	-2043	1241275	-1014487	394618
292	27556	308	-1966	758449	-994231	813718
244	23870	341	-1448	1072559	-944521	2115938
229	22670	352	-1281	1151695	-927289	2468757
167	26299	108	-2410	1446121	-900895	4092091
167	25783	112	-2338	1450983	-900902	4091853
153	25374	116	-2281	1526241	-894328	4449001
153	24905	120	-2216	1523985	-894341	4449642
153	23705	131	-2049	1527565	-894358	4449860
153	27400	-114	-3187	1472951	-896558	4455663
153	27276	-113	-3170	1478527	-896559	4455149
91	23590	-79	-2656	1880402	-908768	6127963
76	26191	-315	-3642	1910032	-923535	6542684
76	26193	-309	-3588	1910790	-923506	6542604
38	-4343	1072	-2660	1613509	-976180	7583927
38	-1878	975	-2778	1539922	-979737	7591137
38	-1878	975	-2778	1539922	-979737	7591137
38	-4343	1072	-2660	1613509	-976180	7583927
76	26193	-309	-3588	1910790	-923506	6542604
76	26191	-315	-3642	1910032	-923535	6542684
91	23590	-79	-2656	1880402	-908768	6127963
153	27276	-113	-3170	1478527	-896559	4455149
153	27400	-114	-3187	1472951	-896558	4455663
153	23705	131	-2049	1527565	-894358	4449860
153	24905	120	-2216	1523985	-894341	4449642
153	25374	116	-2281	1526241	-894328	4449001
167	25783	112	-2338	1450983	-900902	4091853
167	26299	108	-2410	1446121	-900895	4092091
229	22670	352	-1281	1151695	-927289	2468757
244	23870	341	-1448	1072559	-944521	2115938
292	27556	308	-1966	758449	-994231	813718
305	28110	303	-2043	1241275	-1014487	394618
305	37287	2426	2492	1070966	-986730	297915



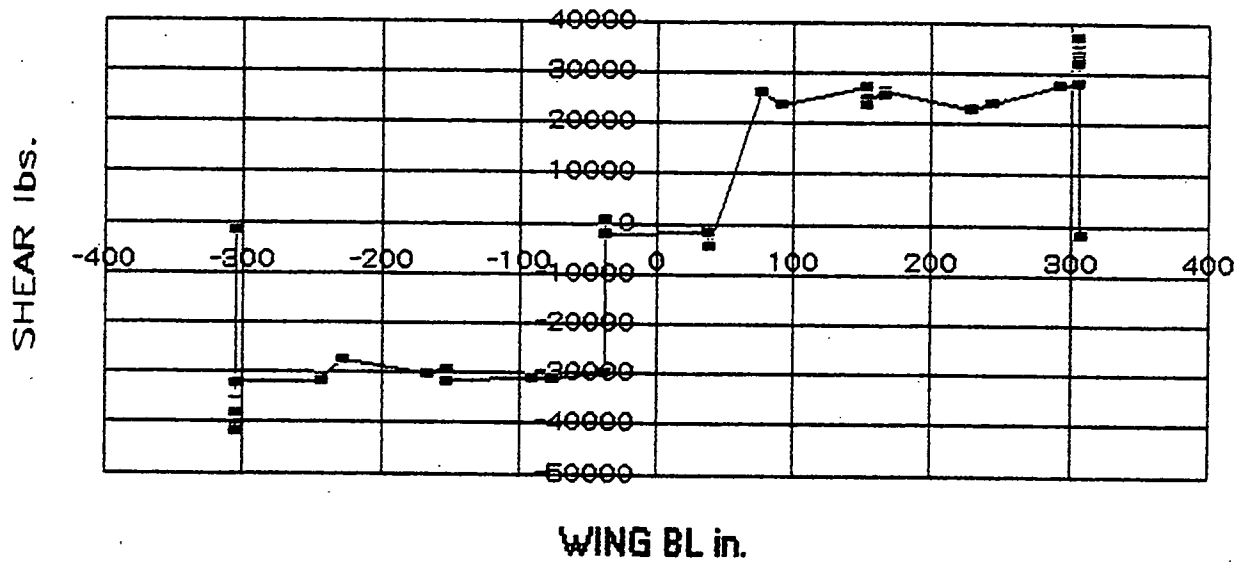
2-F024

Figure 19. Fuselage vertical shear and moment - 110kn - 75° tilt.



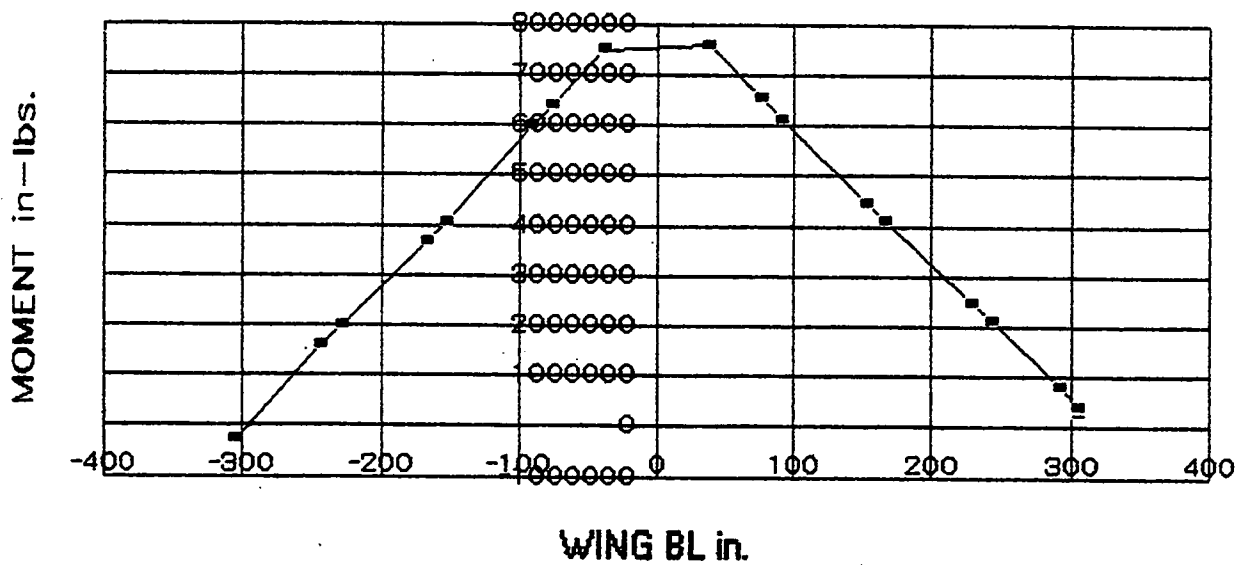
2-F025

Figure 20. Fuselage horizontal shear and moment - 110kn - 75° tilt.



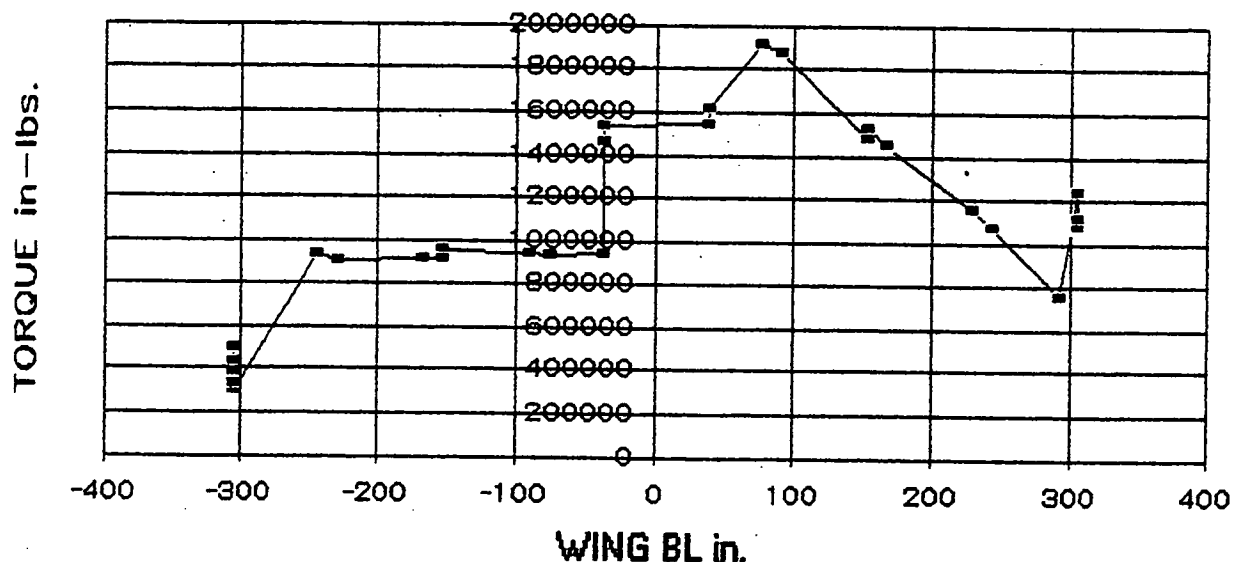
2-F026

Figure 21. Wing shear - 110kn - 75° tilt.



2-F027

Figure 22. Wing moment - 110kn - 75° tilt.



2-F028

Figure 23. Wing torque - 110kn - 75° tilt.

Table 15. Dynamic frequency placement guide for tiltrotor preliminary design.

1. Wing vertical bending frequency shall be less than 80% of wing chord frequency.
2. Wing chord freq shall be approximately 85% of the one per rev for the rotor in the A/C mode
3. Wing torsional freq shall be at least 115% of the one per rev for the rotor in helicopter mode.

The following expressions were used to compute fundamental frequencies for a wing box which is assumed to be constant stiffness and geometry, spanwise, and a pylon inertia calculated from weight and geometry data.

$$\text{Vertical bending} = \frac{1}{2\pi} \sqrt{\frac{3(E I_b)}{M L^3}}$$

$$\text{Torsion} = \frac{1}{2\pi} \sqrt{\frac{K G}{L}}$$

$$\text{Chord bending} = \frac{1}{2\pi} \sqrt{\frac{3(E I_b)}{M L^3}}$$

$$\text{Coupled} = \frac{1}{2\pi} \sqrt{\frac{-b(+ -) \sqrt{b^2 - 4ac}}{2a}}$$

where:

$$a = M \cdot I_{cg}$$

$$b = I_{sc} \cdot k_y \cdot M \cdot k_o$$

$$c = K_y \cdot k_o$$

$$k_y = \frac{3 E I_b}{L^3} = \text{wing bending stiffness}$$

$$k_o = \frac{J L}{L} = \text{wing torsional stiffness}$$

M = Mass of pylon (lb mass)

I_{cg} = Mass moment of inertia of pylon about its CG, (lb_f-sec²-in.)

I_{sc} = Mass moment of inertia of pylon about the shear center of the wing box (lb_f-sec²-in.)

ized effects such as the pylon downstop spring rate, as well as mast and transmission support stiffnesses influence the frequencies and mode shapes also, and should not be neglected in the NASTRAN model or stability assessment. However, the values in Table 15 have been set such that these localized effects can be ignored on the first pass.

Past experience has shown that the wing beam-wise and chordwise and torsional frequencies should be separated from each other, and that increased torsional frequency is generally good for proprotor stability. While these prescribed ranges may be reasonable, they do not guarantee proprotor stability. The interaction of airframe frequencies and mode shapes on proprotor stability is a complex one, and to date, no definitive "rules of thumb" have emerged. The overall design optimization process should include calculation of the coupled frequencies and mode shapes of the wing/pylon, using a detailed finite element model, which are then used in a stability analysis such as the NASA Langley Research Center PASTA code, the NASA Ames Research Center CAMRAD code, or the BHTI ASAP code, to verify adequate stability margins.

In order to compute the frequency response for each of the guide recommendations of Table 15 for each of various stiffness variations, numerous properties of the wing and pylon need to be computed. The spread sheet shown in Table 16 calculates those properties. Mass and mass-moment-of-inertia are shown at the top of the spread sheet for CTR as defined in the weight and geometry of Table 2. Similar data are shown for the V-22. Also shown are the rotor frequencies for the airplane mode (A/P) and helicopter mode (HELO).

The next section of the spread sheet show unit box section properties for each design variation. CATIA drawings were made with unit skin thickness and cap and stringer areas. Section properties for these areas are computed within the CATIA system. These results are shown in Figures 24, 25, and 26. Factors were iteratively applied to each of the properties to achieve a box that met strength requirements. This work developed the trial wing box section properties.

The next portion of the spread sheet list the wing box stiffness and unit weight for various distributions of material between the skin and the

stringers. Additionally, box size is considered in that the 5-55 notation refers to a box with the front spar at 5% chord and the rear spar at 55%. A smaller box results when the front spar is moved back to 10% but the front spar is deeper and its corner caps are more effective. An additional variable is to consider all bending material to be in the spar caps versus universally distributed among the stiffeners. A combined case is also shown. This case is similar to the V-22 however since the V-22 wing chord is larger than the Model 940, the combined case stiffness is quite different.

These mass and section property data were then copied to a second area of the spread sheet where the expressions presented in Table 14 are used to resonant frequencies for each of the various first order mode shapes. This portion of the spread sheet is labeled Table 17. The criteria was used to establish a set of target values. The V-22 results are shown first. The target values versus those computed from the section property data may be compared with the actual measured frequencies. The correlation is certainly satisfactory for the level of analysis conducted here.

Two structural shear center locations are considered. The axis is at 30% chord for an orthotropic box but it may be as far forward as 11% if it is highly anisotropic.

The best fit, as judged by technical personnel in this area, is the combined case at the bottom of Table 16. This analysis was not sufficiently rigorously to recognize the anisotropic case as different from the orthotropic.

MATERIALS AND ALLOWABLES

The structural concepts which will be sized are those that were developed during previous work. That is, the wing will have blade type stiffeners which together with the spar caps will contain all of the bending material. The axial material will be rods of intermediate modulus carbon fiber such as IM7 or G40-800. They will be impregnated with a relatively high modulus epoxy resin and will be 0.070 inches in diameter. The skin and spar webs will be ± 45 orientation tape laminates utilizing the lower cost AS4 or G30-500 fibers.

Table 16. Input data for initial wing stiffness computations.

	CTR	V-22	
Pylon Mass = (lbm)	13.93	16.69	
Pylon Weight (lb) =	5383	6449	
$M \cdot (CG-FS)^2 + I_o = (lb_f \cdot sec^2 \cdot in.)$	24402	42573	
Pylon CG (FS) = (in.)	365	356	
MOM-Inertia, CG = $(lb_f \cdot sec^2 \cdot in.)$	24402	42573	
Shear Center = (in.)	381	375	
MOM-Inertia, SC = $(lb_f \cdot sec^2 \cdot in.^2)$	30427	48598	
Wing Chord (in) =	86	100	A/P 4.84
Semispan (in) =	267	238.8	HELO 6.3 hertz
Unit Section Data with Factors			
BOX	CHORD	FS	RS
GEOMETRY	43	9.64	15.43
5-55			PERIM 113
	Ix	Iy	CEN. X
Skin -.1	657.1	2490.8	26.7
Cap-Corner	151.87	1875	24.64
Cap Dist.	270.7	416.5	25.67
			CEN. Y
			AREA
			FACTOR
			COMBINED FACTORS
			1.85
			0.8
			2.7
BOX	CHORD	FS	RS
GEOMETRY	39	13.4	15.7
10-55			PERIM 107
	Ix	Iy	CEN. X
Skin -.1	637	2029.89	28.26
Cap-Corner	187.31	1453.75	27.63
Cap Dist.	282.14	335.4	27.88
			CEN. Y
			AREA
			FACTOR
			2
			1.9
			2.5
BOX	CHORD	FS	RS
GEOMETRY	45	15	22
V-22A			PERIM 125
	Ix	Iy	CEN. X
Skin -.2	2208	7588	-397
Cap-Corner	309	2625	-396
Cap Dist.	2143	2630	-394
			CEN. Y
			AREA
			FACTOR
			0.9
			0.65
			0.45
Material Properties			
	E	G	DENSITY
Skin	2000000	5400000	0.056
Cap	18000000	1000000	0.056
Skin t	0.1		
Cap A	1		
Trial Wing Box Section Properties			
CORNER CAP	EIb	EIc	KG
5-55	6.53E+09	5.98E+10	1.86E+10
10-55	8.95E+09	5.78E+10	1.83E+10
DISTRIBUTED			lbs/ft
5-55	1.9E+10	3.47E+10	1.86E+10
10-55	1.52E+10	2.32E+10	1.83E+10
V-22	2.6E+10	9.69E+10	1.95E+10
V-22A	2.49E+10	6.57E+10	1.82E+10
COMBINED	1.56E+10	5.56E+10	1.86E+10

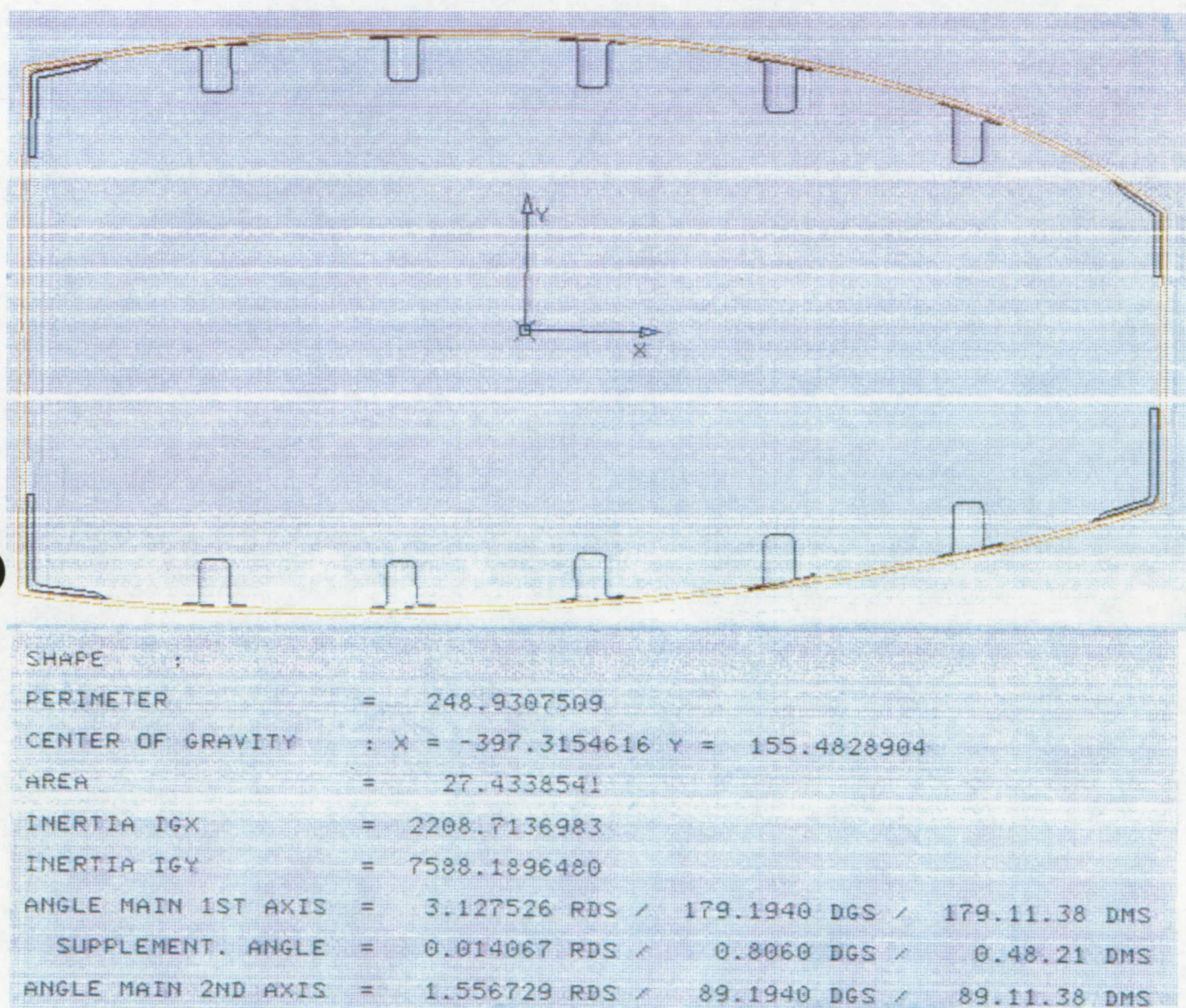
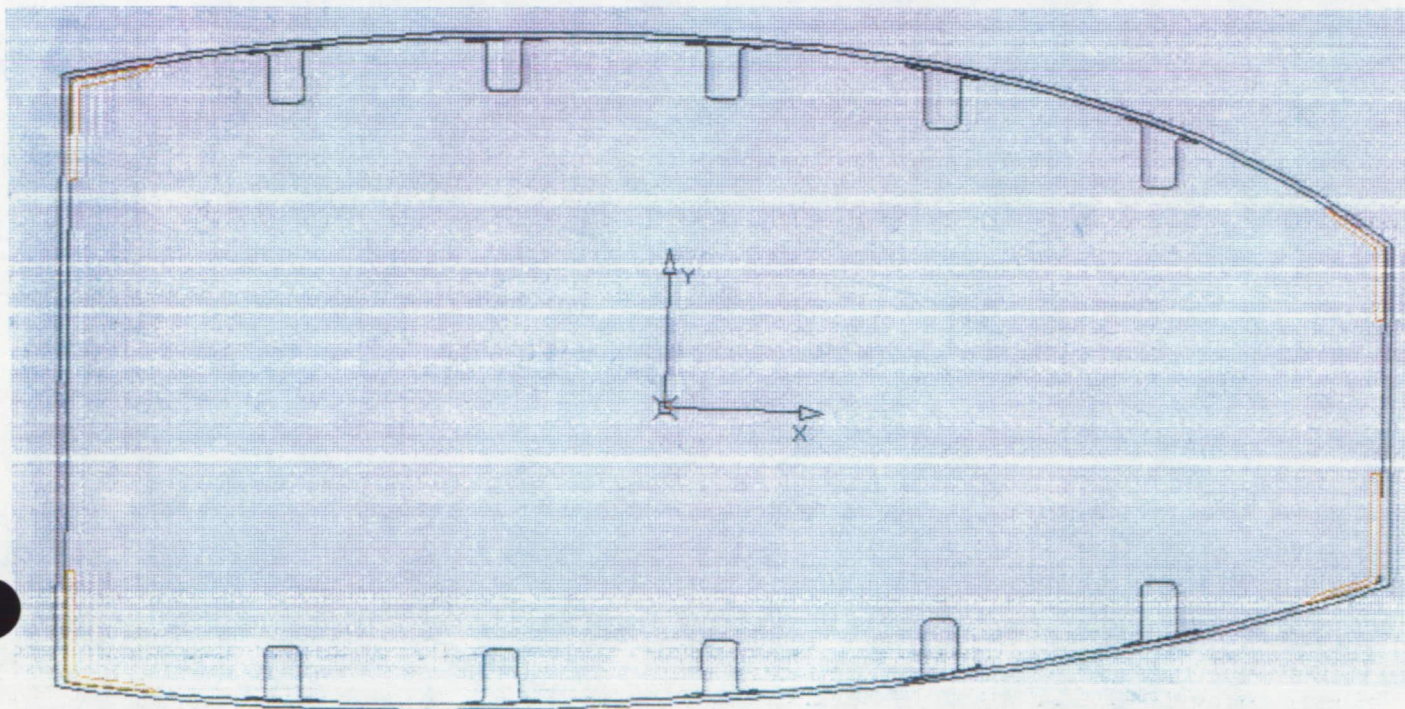
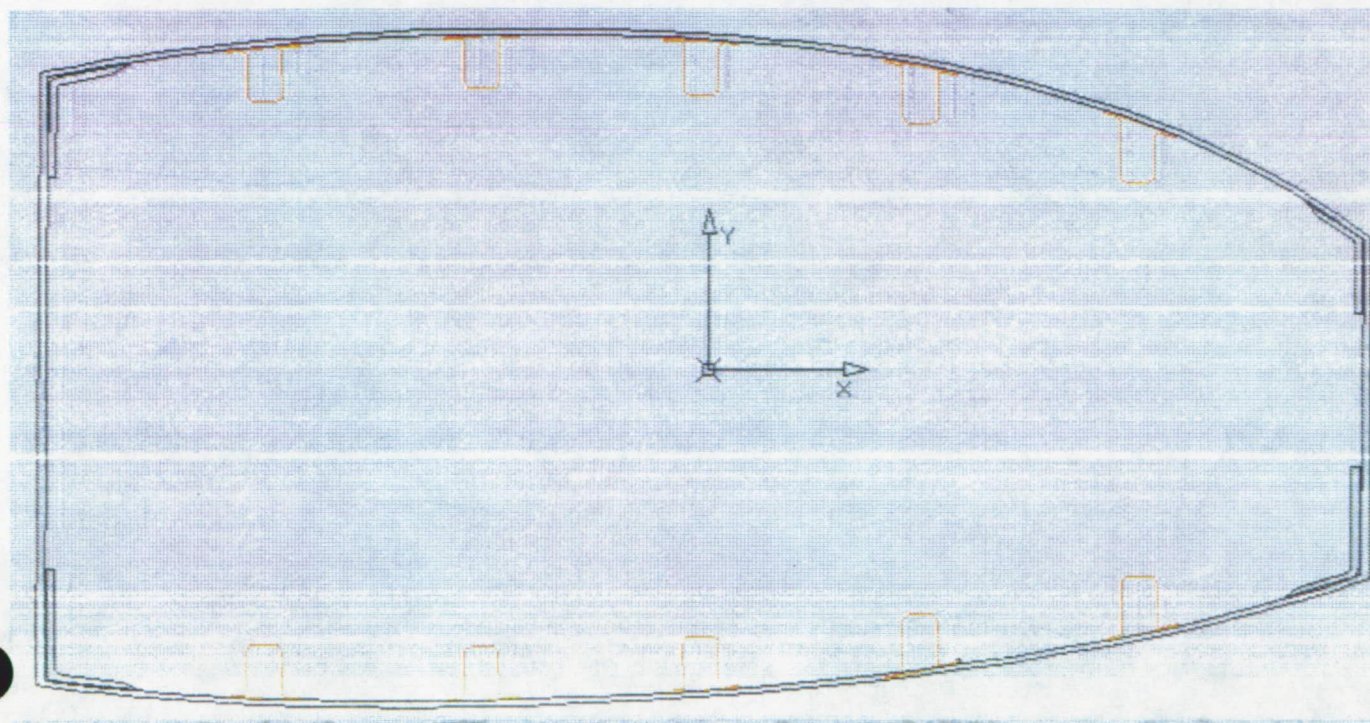


Figure 24. Unit wing skin and spar inertia.



SHAPE :
 PERIMETER = 47.9339921
 CENTER OF GRAVITY : X = -396.5858292 Y = 154.5498532
 AREA = 5.5018284
 INERTIA IGX = 309.5427068
 INERTIA IGY = 2625.9865747
 ANGLE MAIN 1ST AXIS = 3.114168 RDS / 178.4287 DGS / 178.25.43 DMS
 SUPPLEMENT. ANGLE = 0.027424 RDS / 1.5713 DGS / 1.34.16 DMS
 ANGLE MAIN 2ND AXIS = 1.543372 RDS / 88.4287 DGS / 88.25.43 DMS

Figure 25. Unit wing skin and spar inertia.



```

SHAPE      :
PERIMETER  =      85.3947568
CENTER OF GRAVITY : X = -394.3906852 Y =  155.7482756
AREA       =      23.2771466
INERTIA IGX =      2142.8311295
INERTIA IGY =      2630.3303924
ANGLE MAIN 1ST AXIS =    0.002862 RDS /    0.1640 DGS /    0. 9.50 DMS
SUPPLEMENT. ANGLE  =    3.138730 RDS /   179.8360 DGS /   179.50. 9 DMS
ANGLE MAIN 2ND AXIS =    1.573658 RDS /    90.1640 DGS /    90. 9.50 DMS

```

Figure 26. Unit stringer inertias.

Table 17. Frequency and mode shape comparisons - V-22 and Civil Tiltrotor.

Vehicle Data

	CTR	V-22
Pylon Weight (lbs.)	5383	6449
Pylon Inertia @ CG ($Lb_f \cdot sec^2 \cdot in.$)	24402	42573
Wing Structural Axis		
@ 30% chord (in.)	381	375
@ 7% & 11% (in.)	361	356
Pylon Inertia @ Wing Shear Center		
@ 30% chord (in.)	30427	48598
@ 7% & 11% (in.)	24977	42573
Helicopter 1/rev hertz	6.3	6.6
Airplane 1/rev hertz	4.8	5.5

V-22 Computed vs Actual Frequencies

	LOW	VERT	CHORD	TORQUE	HIGH
Criteria Target	2.2	3.7	4.7	6.3	
Actual		2.9	4.7	5.2	
Axis @ 30%	2.8	2.9	4.7	6.3	6.8
Axis @ 11%	2.9	2.9	4.7	6.7	6.7

CTR Computed vs Actual Frequencies

	LOW	VERT	CHORD	TORQUE	HIGH	WT.
Criteria Target	1.9	3.3	4.1	7.6		
Axis @ 30%						
High Vertical	2.1	2.1	2.6	7.6	8.5	21.1
High Chord	1.4	1.4	4.1	7.6	8.5	18.3
High Torque	1.6	1.6	4.1	7.6	8.5	19.6
Axis @ 7%						
High Vertical	2.1	2.1	2.6	8.3	8.4	
High Chord	1.4	1.4	4.1	8.4	8.5	
High Torque	1.6	1.6	4.1	8.3	8.5	

CTR with Combined Distributed and Corner Caps

	LOW	VERT	CHORD	TORQUE	HIGH	WT.
Criteria Target	1.9	3.3	4.1	7.6		
Axis @ 30%						
Combined	2.1	2.1	4.0	7.6	8.6	23.6

The fuselage will utilize a ± 45 orientation tape laminate skin of AS4 or G30-500 fiber in a toughened epoxy matrix. Shallow stringers and hat shaped ring frames will stiffen the structure and react bending and pressure loads. Longerons as required will be on the outside of the fuselage and are only required to distribute loads which are out of the plane of the skin to several ring frames. This occurs at the landing gear and the wing attachment area. The axial load carrying portions of the stringers, longerons and ring frames will be rods of 0.050 to 0.070 inches in diameter.

Rods

A new material form, the "rod", was introduced during the previous study. The term rod, as described here, refers to a cured, carbon fiber and plastic matrix small diameter continuous rod wherein the fibers within the rod are straight or nearly straight. Since its introduction, Bell Manufacturing Development engineers have been learning how to maximize the structural performance of the rod and of the overall structure in which the rod is included. A machine has been built to assemble 20 rods with Syncore form and bias plied tape in preparation for lay-up. Bell engineers have been examining the load introduction problem relative to different size rods. In addition, Bell engineers have approached two fiber producers, BASF and Hercules, and one glass rod manufacturer, NEPTCO, for a commitment to develop and produce the rod of straight fibers. Recognizing that there is no such thing as a perfectly straight fiber, the "rod" has been defined as possessing an angularity standard deviation of .88 degrees as determined by measuring the elliptical sections of the fibers when cut at a 5 degree angle. At this point, none of the three have accepted the challenge but agreement with one of the companies appears imminent.

It is intended that the rod will be made with IM7 fiber from Hercules or G40-800 fiber from BASF. Figure 27 shows the theoretical relationship between fiber straightness and rod modulus for the IM7 fiber. The typical waviness of the best of current prepreg and flat laminate lay-up is believed to pose an A/L of 1.2%. The .88 standard deviation value is intended to be equivalent to an A/L of .9%. Thus the modulus of the rod is

expected to be 23 msi and the degree of nonlinearity, or loss in modulus in compression, will be greatly reduced.

Figure 28 shows the theoretical relationship between fiber straightness and rod compression strength for the IM7 fiber. At an A/L of .9%, the compression strength is expected to be 300 ksi.

Because IM7 and G40-800 are high cost fibers relative to AS4 or G30-500, 50 vs. 15 \$/lb, rod will also be made with these lower cost fibers, initially G30-500.

Both the BASF and the Hercules fiber lines have been examined in detail as to the source of waviness in the tow, and both manufacturers are focusing their efforts on minimizing waviness in their product.

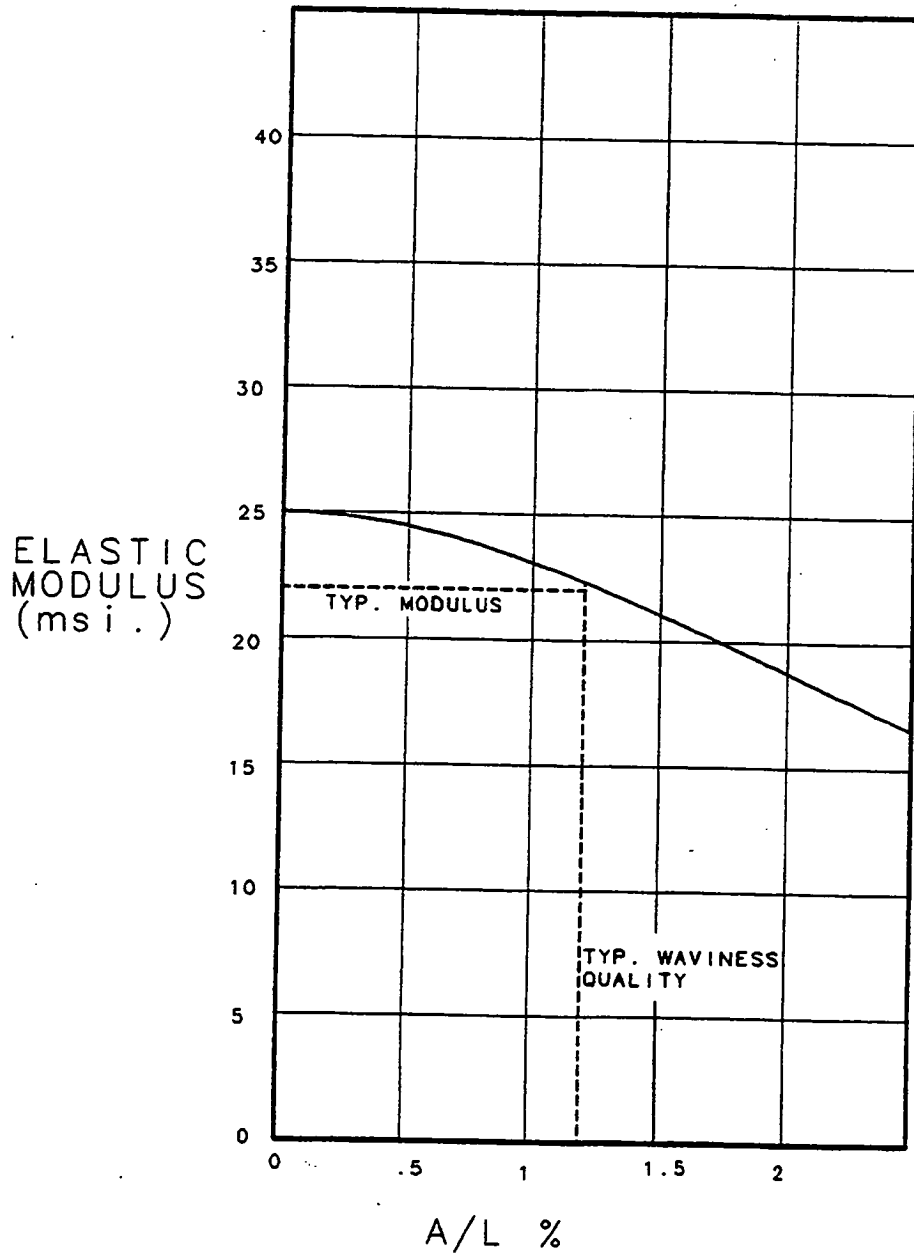
NEPTCO is the largest producer of fiber glass rod for the optical cable industry. Their process appears to be ideally suited to the manufacture of rod with the least damage to the fiber and a reasonable opportunity to average out the inherent waviness found in the tow.

Skins

Skin material will be all bias (± 45) orientation for shear strength and stiffness and damage tolerance. The lower cost fibers, AS4 or G30-500, will be utilized for this application as the higher strengths of the more expensive fibers are probably not warranted. The properties of a toughened resin such as E7T1 from US Polymeric or a three constituent system such as 8551 from Hercules will be used for this study. Typical laminate properties are shown in Table 18.

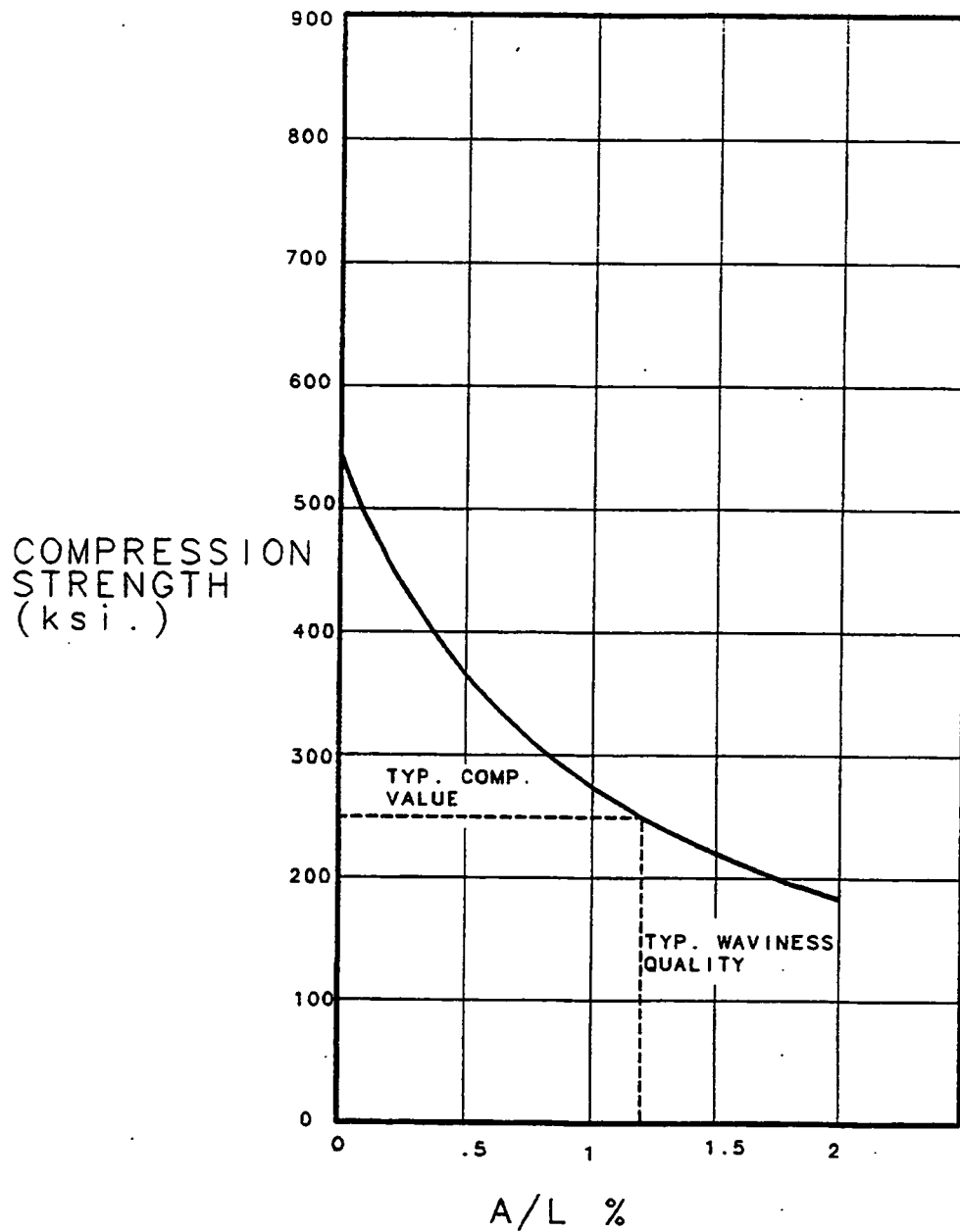
Allowables

Strength allowables shall be assumed to be 80% of typical properties as presented above. Stiffness shall not be reduced from the mean for variability. However, the primary strength constraints for composite design are not these basic material properties but special constraints due to the possibility of an undetected impact damage or local stress concentration due to an open or loaded, fastener size, hole. Typical strain



2-F035

Figure 27. Modulus vs A/L for IM7/epoxy.



2-F036

Figure 28. Modulus vs A/L for IM7/epoxy.

Table 18. Typical laminae properties for IM7/E7T1 tape.

Mechanical Test	Test Temperature, Test Condition	IM7/E7T1-2 190 g/m ² Uni-Tape, Batch 2W6962	IM7/EUT1-2 95 g/m ² Uni-Tape, Batch 2W6935
		(Strength*/Strain/ Modulus*/ Poissons Ratio) (ksi/%/Msi/--)	(Strength*/Strain/ Modulus*/ Poissons Ratio) (ksi/%/Msi/--)
Zero-Deg Tensile	-67 Deg F, dry 75 Deg F, dry 220 Deg F, wet 250 Deg F, dry	(389/1.575/23.1/0.329) (379/1.569/23.6/0.314) (354/1.429/23.5/0.349) (358/1.453/23.3/0.337)	(423/1.620/24.3/0.328) (406/1.581/24.3/0.320) (357/1.408/24.5/0.354) (383/1.524/24.4/0.303)
Zero-Deg Compressive	-67 Deg F, dry 75 Deg F, dry 220 Deg F, wet 250 Deg F, dry	(270/--/19.2/--) (258/--/21.2/--) (188/--/20.9/--) (192/--/19.8/--)	(272/--/20.9/--) (246/--/22.6/--) (170/--/24.2/--) (205/--/23.0/--)
Ninety-Degree Tensile	-67 Deg F, dry 75 Deg F, dry 220 Deg F, wet 250 Deg F, dry	(9.05/0.633/1.45/0.028) (10.8/0.849/1.35/0.019) (5.08/0.817/0.85/0.023) (8.78/1.146/1.10/0.024)	(9.21/0.663/1.42/0.019) (8.91/0.715/1.30/0.017) (5.18/1.173/0.75/0.014) (8.86/1.370/1.10/0.018)
45 Deg Intralaminar Shear	-67 Deg F, dry 75 Deg F, dry 220 Deg F, wet 250 Deg F, dry	(16.3/--/0.900/--) (19.4/--/0.815/--) (12.5/--/0.502/--) (14.5/--/0.578/--)	(31.9/--/0.943/--) (27.3/--/0.840/--) (13.9/--/0.419/--) (16.5/--/0.578/--)
Zero-Deg Interlaminar Shear (SBS)	-67 Deg F, dry 75 Deg F, dry 220 Deg F, wet 250 Deg F, dry	(20.0/--/--/--) (15.5/--/--/--) (6.45/--/--/--) (8.73/--/--/--)	(18.8/--/--/--) (14.7/--/--/--) (5.77/--/--/--) (8.28/--/--/--)
Open-Hole Tensile Strength	-67 Deg F, dry 75 Deg F, dry 220 Deg F, wet 250 Deg F, dry	(68.3/--/--/--) (69.9/--/--/--) (68.8/--/--/--) (69.5/--/--/--)	(67.3/--/--/--) (67.9/--/--/--) (62.9/--/--/--) (67.4/--/--/--)
Open-Hole Compressive Strength	-67 Deg F, dry 75 Deg F, dry 220 Deg F, wet 250 Deg F, dry	(53.8/--/--/--) (48.1/--/--/--) (36.6/--/--/--) (34.9/--/--/--)	(57.9/--/--/--) (50.7/--/--/--) (40.1/--/--/--) (43.1/--/--/--)
Compression-After-Impact Strength	-67 Deg F, dry 75 Deg F, dry 220 Deg F, wet 250 Deg F, dry	(38.1/--/--/--) (37.9/--/--/--) (/--/--/--) (33.4/--/--/--)	(39.6/--/--/--)
Compression-After-Impact Strength per NASA 1092	75 Deg F, dry	(45.5/--/--/--)	(56.0/--/--/--)
Strain-Energy Release Rate (G _{IC}) per double cantilever test procedure	75 Deg F, dry	(2.82 in-lb/in ²)	(2.67 in-lb/in ²)

Notes: *Normalized test results except ninety-degree tensile and zero-deg interlaminar shear (SBS).

allowables for these failure modes are in the order of 3500 micro inches per inch.

The compression-after-impact strength is defined by the instability of the sublaminae created by the delamination process of impact. Delamination is the direct result of exceeding the through-the-thickness shear strength of the laminae which is in reality related to the transverse tensile strength of the lamina. More importantly, the shear stress, which is a function of the local deformation, can be sufficiently low for thick laminates to avoid delamination. The blade stiffeners of the wing are expected to be very stiff and therefore will not delaminate under the specification requirement for maximum impact of 100 ft-lbs. Thus, the compression-after-impact strain allowable for this wing concept will be assumed to be above .6% strain.

The skins are all bias orientation and have been shown by test to possess a strain allowable above .6% even after sustaining a delamination. The reason for this anomaly is that the laminate modulus is low since it contains no zero degree plies, therefore this relatively high, .6% strain, results in a low axial load. It is the load that causes buckling and propagation of the delamination.

The remaining consideration is the effect of holes. The design concept is such that all mechanical attachment is accomplished in the all bias ply material. The strain allowable with all bearing interactions considered is above .6% for this laminate. There will be no holes by design in the rod or axial material and any hole that is accidentally drilled in this material can readily be found upon inspection and repaired. Thus, there will be no knockdown factor for holes below the .6% strain allowable.

CIVIL TILTROTOR WING BOX

Only the wing box, center fuselage and wing fuselage intersection of the Model 940A CTR has been examined in this study.

The wing box for the Model 940A, shown in cross section in Figure 29, extends from the front spar at 5% chord to the rear spar at 55% chord where the chord is 86 inches measured along a buttock line. The airfoil of the Model 940A is similar to

the V-22 but has a t/c of 21.6% where the V-22 is 23%. Airfoil coordinates are provided in Appendix A, Table A-1 and compose Figure A-1. There are five blade stiffeners equally spaced along the chord plane. The spar caps are composite angles which are co-cured with the skin and blades on a female tool. The ribs are carbon-thermoplastic formed as an integrally stiffened pan. The wing box shown in planform in Figure 30 locates the ribs and dihedral and sweep break point.

Table 19 lists the skin gage, stringer and spar cap axial area at specific span stations. Wing bending, spanwise and chordwise strains as well as torsion strains are shown for two flight conditions. The assumed allowable for this construction is 0.6% strain tension and compression and 0.45% shear. Due to preliminary nature of these calculations, if the resulting strain from a load condition was computed to be within 10% of the assumed allowable, no further iterations were conducted.

Since this study was conducted, numerous tests of this construction have been conducted on this construction concept. At this point there is no justification to change this assumed allowable.

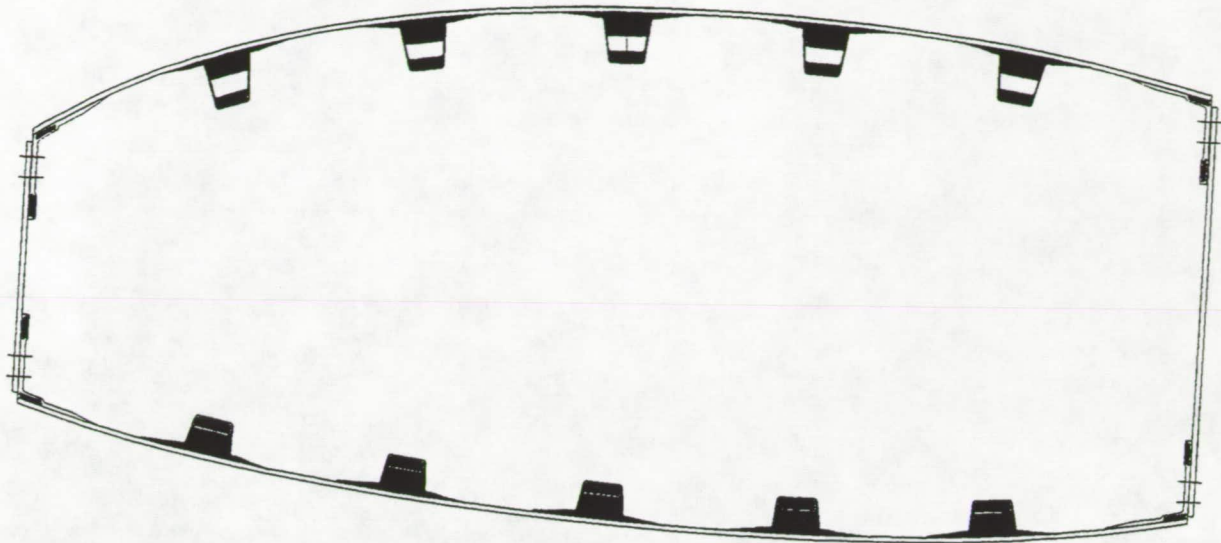
The last portion of Table 19 shows a preliminary check of Euler buckling of the hat stringers. These results show the design is probably acceptable when all factors are properly considered.

The wing skins, shown in Figure 31 are bonded to the ribs and the front and rear spar webs are mechanically attached. The spar webs are made in short sections such that access for maintenance or repair is accomplished by removal of a spar web section.

CIVIL TILTROTOR CENTER FUSELAGE

A section of the fuselage for the Model 940A at FS300 is shown in Figure 32. This section defines the longeron and stringer locations as well as the floor beam. The profile view, Figure 33, defines the frame stations and the limits of the center section. Table 20 lists the element sizes for the details of stringer and ring frame.

The center fuselage skins for the Model 940A are made in four sections and stringers are made integral with the skins. The skins are bonded to



2-F067

Figure 29. Wing box section.

each other and the ring frames at the same time. The ring frames are mechanically spliced at the buttock line zero, top and bottom.

Wing Fuselage Intersection

The Model 940A departs from the V-22 significantly in this area since the CTR has no requirement for wing folding as found with the V-22. The wing for the Model 940A passes above the fuselage and is mounted to the vertical sides of hat shaped longerons which are mechanically attached to the fuselage. These longerons are deep, relatively stiff beams which distribute the concentrated wing attachment loads at the wing box front and rear spar and BL38 to the fuselage ring frames. This longeron is shown in isometric view in Figure 5 and in cross section at FS400 in Figure 6.

This longeron is mechanically attached to the fuselage skin and ring frames. A metal fitting mounts to the vertical side of the longeron and to the spar webs of the box. Lateral forces are reacted by an internal bulkhead in the longeron located at each fitting.

Main Landing Gear Bay

The main landing gear is mounted between two beams which span across the fuselage just under the floor. Longerons similar to those for the wing attachment react all landing gear loads from the beams. Pressure containment is provided by the wheel well liners. Flexible seals would allow the beams and the pressure skin to flex independent of each other.

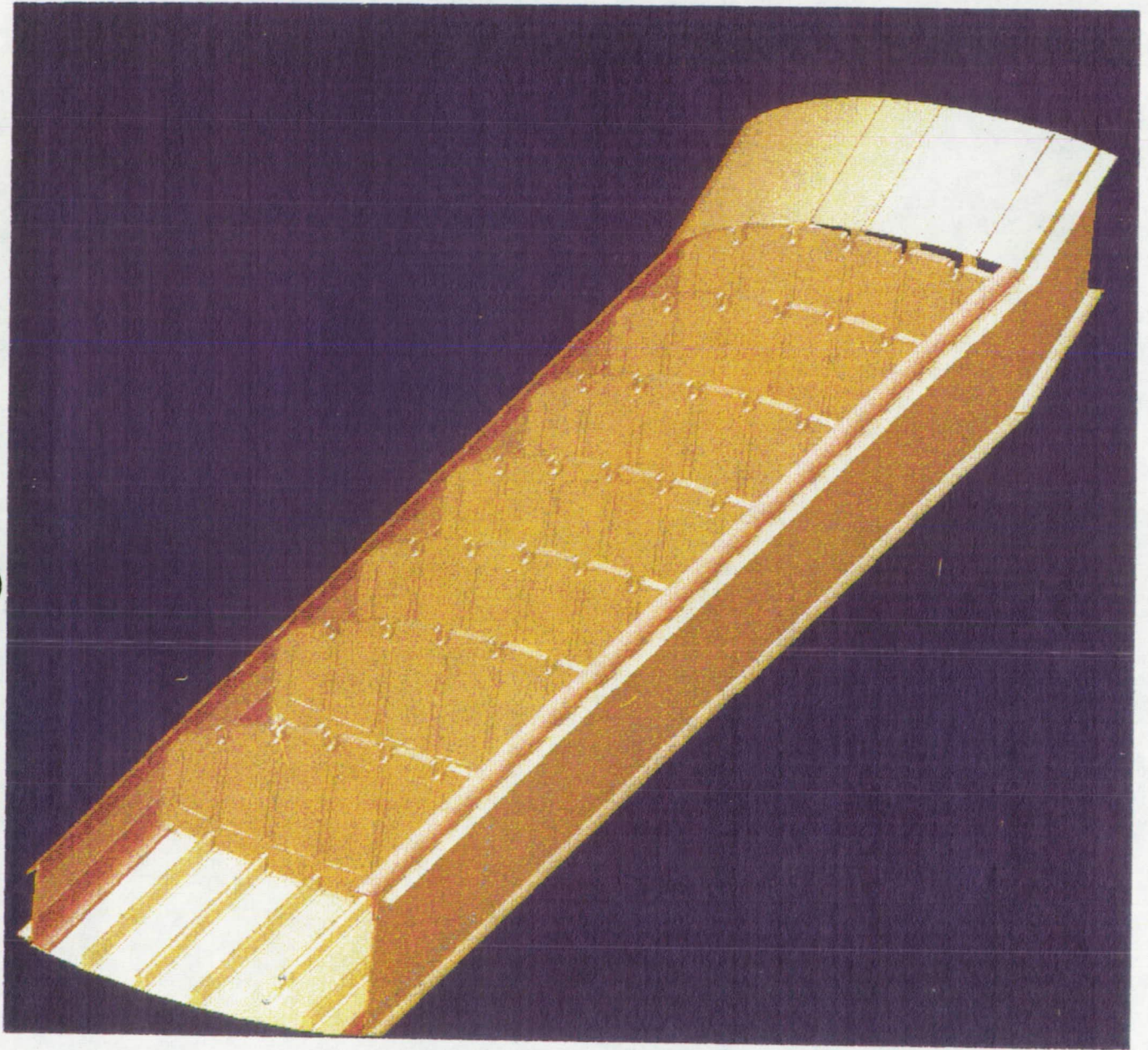


Figure 30. Wing box planform.

Table 19. Wing element sizing.

Factors				Properties		
BL(in.)	Skin	Dist.	Corner	Elb(lb-in.^2)	Elc(lb-in.^2)	KG(lb-in.^2)
38	1.85	3.5	0.9	1.95E+10	6.58E+10	1.86E+10
76	1.85	2.7	0.8	1.56E+10	5.65E+10	1.86E+10
153	1.85	1.6	0.9	1.02E+10	5.16E+10	1.86E+10
300	2	1	0.9	7.5E+09	4.78E+10	2.01E+10
Load/Strain for Condition - 110kn, 75 Tilt						
BL(in.)	Mb(in.-lb)	eb%	Mc (in.-lb)	ec%	Torque (in.-lb)	et%
38	7200000	0.526549	2000000	0.0957	-380000	-2137.57
76	5900000	0.539382	2000000	0.111588	100000	562.5192
153	3800000	0.529458	2000000	0.122126	160000	900.0308
300	2000000	0.379949	2000000	0.131702	900000	4682.973
Load/Strain for Condition - 2G Jump 6 Degree Nose Up						
BL(in.)	Mb (in.-lb)	eb%	Mc (in.-lb)	ec%	Torque (in.-lb)	et%
38	8170000	0.597487	878000	0.042012	-380000	-2137.57
76	7310000	0.668285	775000	0.04324	100000	562.5192
153	5350000	0.745421	544000	0.033218	160000	900.0308
300	63800	0.01212	6200	0.000408	900000	4682.973
Element Data						
BL(in.)	Skin	Stringer Cap		Actual		
	Gage (in.)	Area (in.^2)	Area (in.^2)	Dist.		
38	0.185	1.407	0.97155	1.43025		
76	0.185	1.0854	.08636	1.14675		
153	0.185	0.6432	0.97155	1.005		
300	0.2	0.402	0.97155	0.86325		
			Corner =	1.03		
Stringer Inertia and Buckling Allowable						
Layers of Rods						
BL(in.)	Inner	Outer	ti (in.)	to (in.)		
38	4	7	0.335	0.578		
76	4	5	0.335	0.416		
153	4	4	0.335	0.335		
300	4	3	0.335	0.254		
Stringer						
BL(in.)	Ycg (in.)	Icg (in.^4)	roe (in.)	L/roe (in.)	Euler (% strain)	
38	0.798976	1.667203	1.028018	42.80081	0.005388	
76	0.824603	1.53472	1.089022	40.40323	0.006046	
153	0.857091	1.490111	1.137166	38.69269	0.006592	
300	0.908194	1.462145	1.195809	36.79519	0.00729	

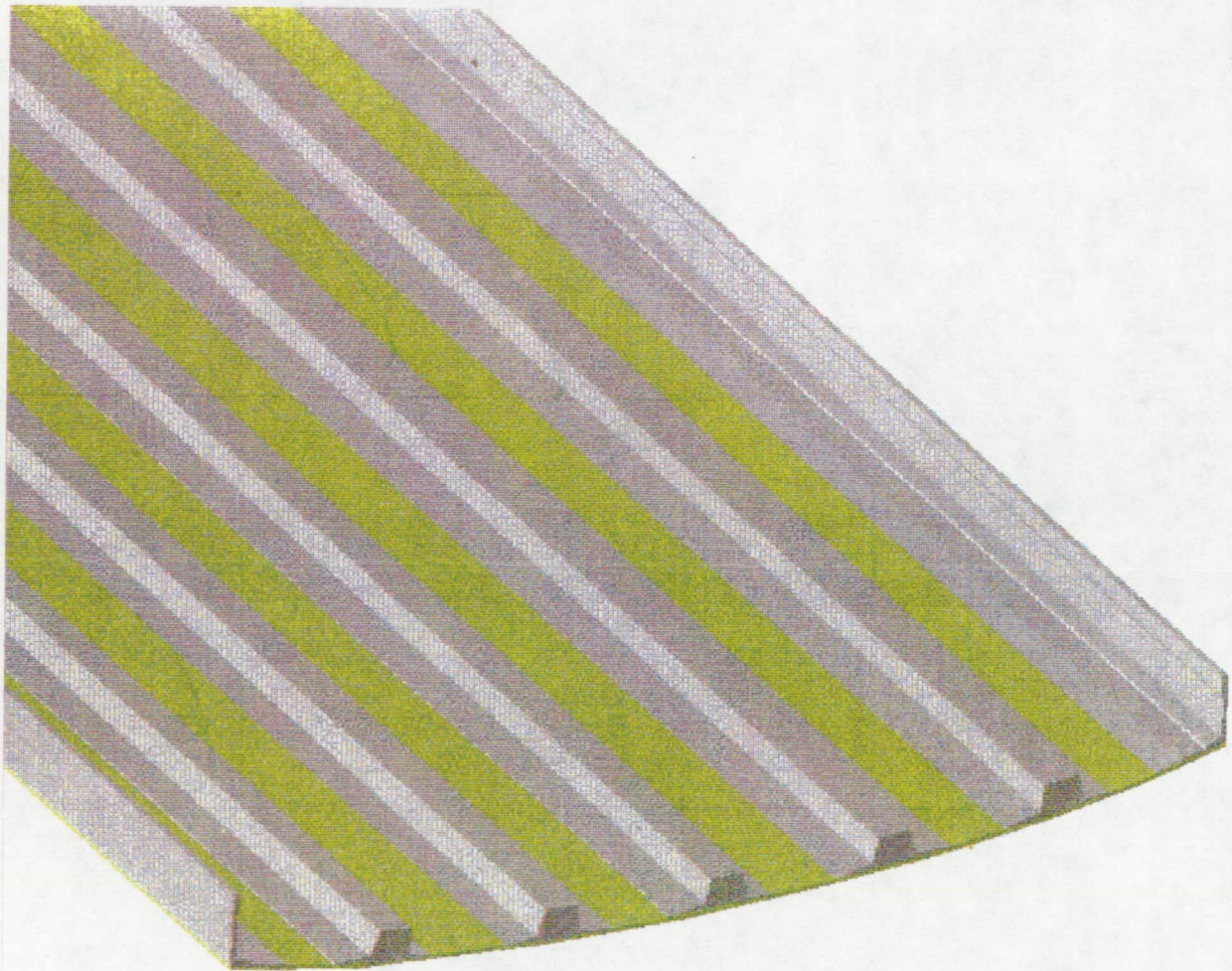
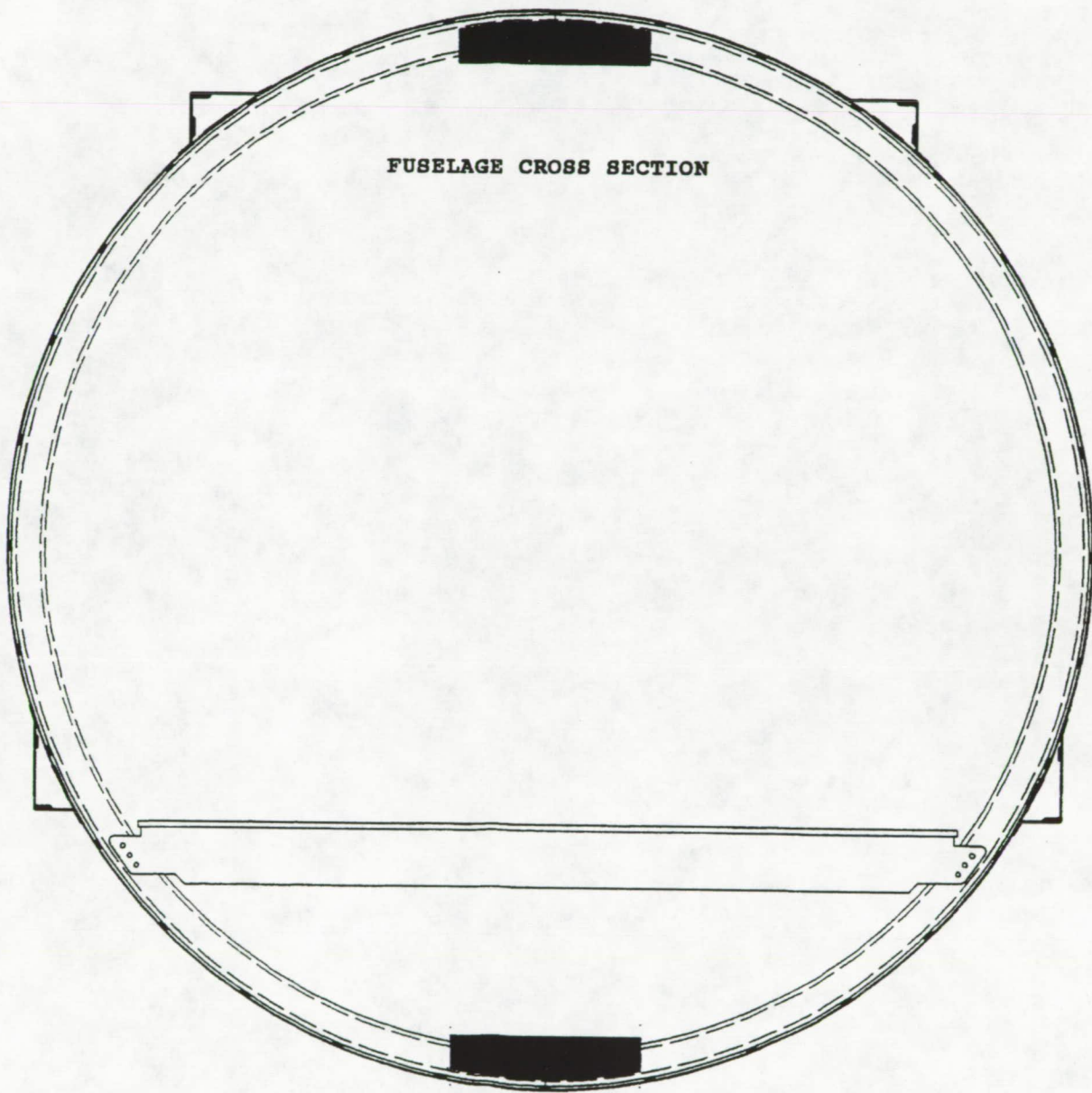


Figure 31. Detail of skin and stringer.



2-F070

Figure 32. Fuselage section FS300.

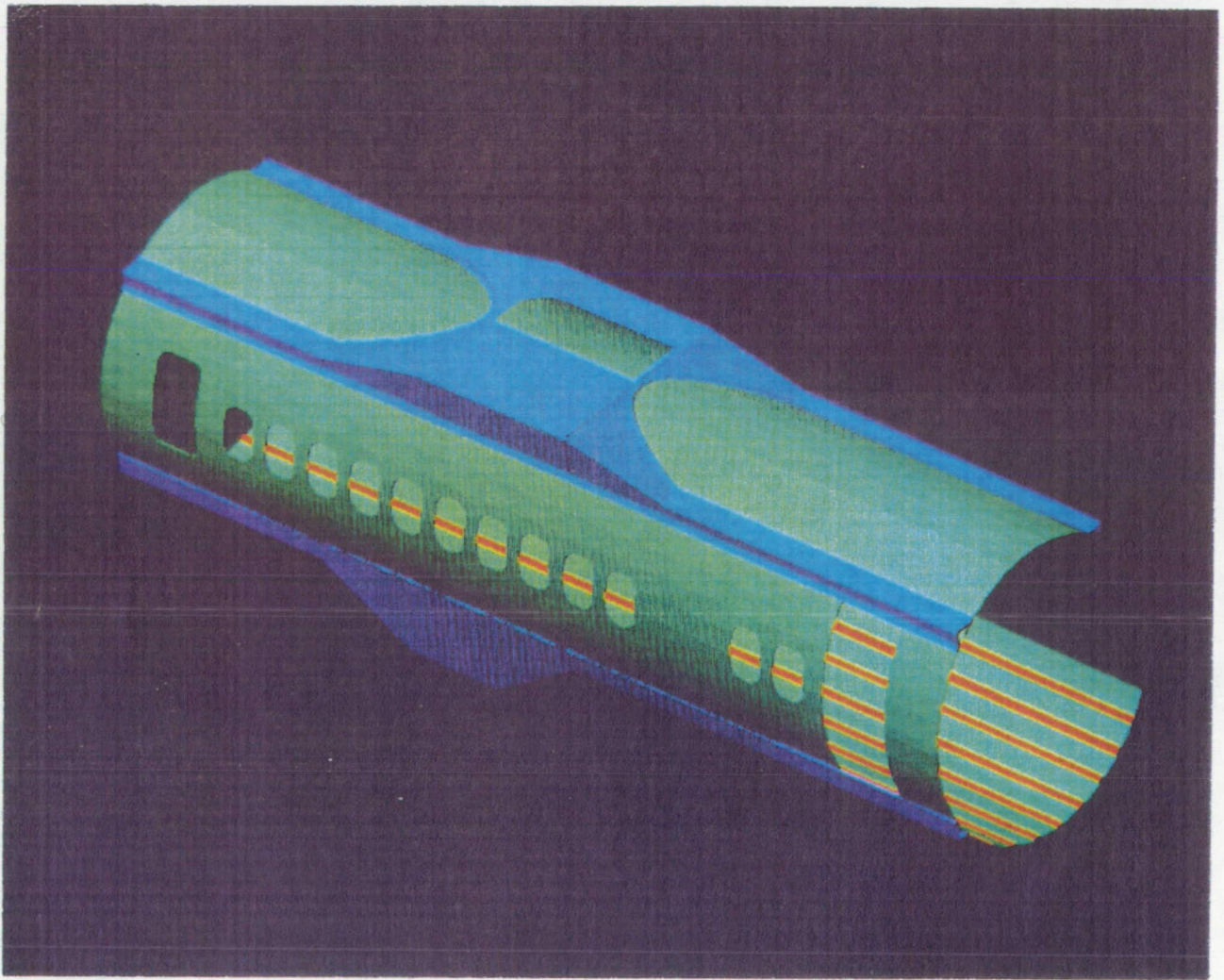


Figure 33. Fuselage profile.

Table 20. Fuselage element sizing.

Constituant Properties

Type	E (psi)	G (psi)	Density (lb/in. ³)	Thick (in.)	Stringer t(in.)
Bias Tape	2000000	5400000	0.057	0.011	
Rod	23000000	800000	0.05	0.07	0.05
Syncore	290000	145000	0.018		

Element Material Properties

Element	Lay-up	E	G	t	Weight (lb-in.)	Width (in.)
Skin	[(+ -45)3/.01SYN]8	1.60E+06	4.21E+06	0.086	0.049	
Stringer	[0.05R1/0.1 SYN]8	7.86E+06	3.63E+05	0.300	0.103	1
Longeron	[0.7R/+ -45]4	2.01E+07	1.42E+06	0.324	0.198	2
Window	[0.7R/+ -45]3	2.01E+07	1.42E+06	0.243	0.149	2
L-Ring						
H-Ring						
Floor B.						

Fuselage Section Properties

Element	Io (in. ⁴)	A (in. ²)	x (in.)	Ax (in. ³)	AX ² (in. ⁴)
Skin	19382.84	39.40	0.00		
Stringer 1		0.30	0.00	0.00	0
Stringer 2		0.30	11.13	3.34	37
Stringer 3		0.30	21.82	6.55	143
Stringer 4		0.30	31.67	9.50	301
Stringer 5		0.30	31.67	9.50	301
Stringer 6		0.30	40.31	12.09	487
Window 7		0.36	47.40	17.28	819
Window 8		0.36	55.90	20.38	1139
Stringer 9		0.30	57.00	17.10	975
Stringer 10		0.30	55.90	16.77	938
Stringer 11		0.30	52.66	15.80	832
Stringer 12		0.30	47.39	14.22	674
Stringer 13		0.30	47.39	14.22	674
Stringer 14		0.30	40.30	12.09	487
Stringer 15		0.30	31.67	9.50	301
Stringer 16		0.30	11.12	3.34	37
Upper Longeron		0.65	37.00	23.98	887
Lower Longeron		0.65	53.00	34.34	1820

Fuselage Properties

	Elx (lb in ²)	Ely (lb in ²)	W-lb/ft
with longeron	2.02E+11	1.8E+11	6.09
without longeron	1.59E+11	1.77E+11	5.30

CONCLUSIONS

This study has produced a reasonable starting configuration for an economical Civil Tiltrotor transport. Geometry, weight and loads have been defined in some detail. The concepts proposed have been reviewed and stood the test of reexamination as applied to the Model 940A. However, where the wing geometry of previous work was the V-22, the wing for this study has a much smaller chord, (86 in. vs 100 in.), and thinner section, ($t/c = 21.6\%$ vs 23%). The result of the reduced box section coupled with a more powerful rotor thrust capability significantly increased the wing loads. Both the thinner airfoil and the increased rotor thrust capability are the result of higher cruise speed of the CTR compared to the the V-22. As a result, flight loads, not rotor stability stiffness requirements, designed the wing in vertical bending. Chordwise bending stiffness defined the spar cap area. The torsional stiffness requirements sized the skin.

The assumptions made regarding the selected design maneuver conditions are based on judgment and V-22 background and, thus, are subject to further scrutiny in the design process.

The result of these assumptions is certain conditions which result in, possibly unreasonable, high loads. For instance, on climb out when the pilot has full rotor thrust capability at a nacelle angle of 75 degrees and a major portion of wing lift due to forward speed, the structure is subjected to over 3-G's vertical acceleration. This condition generates significantly more wing root moment than either the 2-G jump take off or the 4-G symmetrical pull-up condition. It could be argued that this condition is not likely to occur in a civil transport. The fact is that power is available to the pilot and he might chose to use it in an emergency. Thus, either the structure must be designed for these loads or other limitations, such as those provided by control laws, must be modified and control limiting devices must be provided.

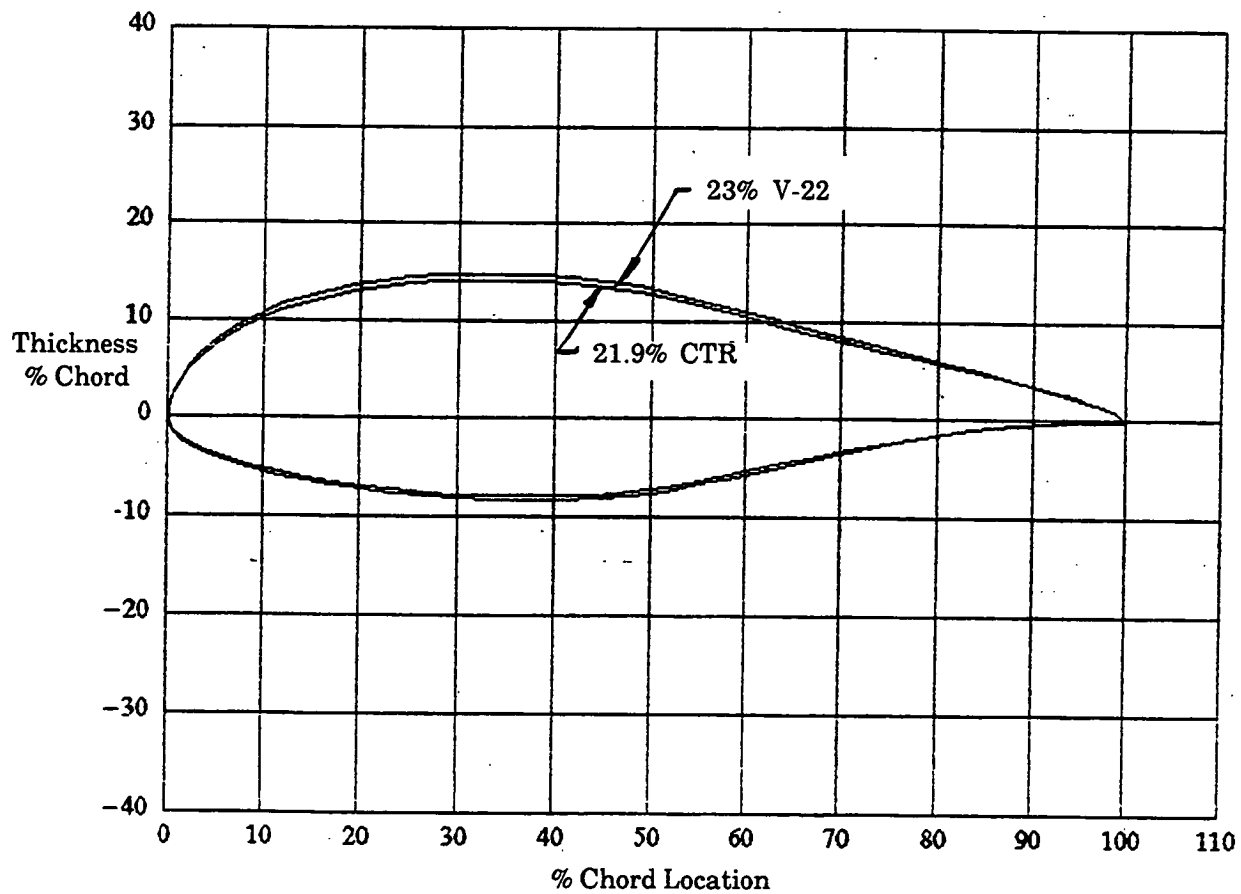
The structural sizing data are presented with which to construct a model for structural optimization purposes.

APPENDIX A
CIVIL TILE ROTOR WING AIRFOIL, PRELIMINARY

Table A-1. Model 94A airfoil coordinates

UPPER SURFACE		LOWER SURFACE	
X =	Y =	X =	Y =
0.03526	0.4479217	0.02838	-0.368491
0.24252	1.3511348	0.27606	-1.039145
0.63812	2.3083933	0.85742	-1.613173
1.2169	3.2934934	1.76472	-2.179012
1.9737	4.2851444	2.94636	-2.735024
2.9068	5.2587803	4.38084	-3.276297
4.0248	6.1955671	6.0501	-3.797098
5.33028	7.0930482	7.9378	-4.291695
6.81206	7.9446725	10.02846	-4.755176
8.4624	8.7340628	12.30574	-5.184263
10.2813	9.4497548	14.75244	-5.572407
12.2636	10.090111	17.3505	-5.917151
14.39898	10.64858	20.08272	-6.211945
16.6797	11.114517	22.92932	-6.452692
19.10146	11.48874	25.86966	-6.6353
21.65136	11.767975	28.88482	-6.753217
24.32252	11.953039	31.9533	-6.800712
27.09774	12.048028	35.0536	-6.768776
29.95896	12.05376	38.16164	-6.646764
32.88382	11.969416	41.25334	-6.408473
35.85168	11.787627	44.3416	-6.003133
38.8419	11.50348	47.49866	-5.429924
41.82438	11.080124	50.75806	-4.757632
44.86276	10.473342	54.09142	-4.050129
48.01896	9.7609252	57.46434	-3.340988
51.24482	9.014935	60.83726	-2.664602
54.49476	8.2550241	64.16804	-2.042261
57.72922	7.5008452	67.41368	-1.495256
60.9138	6.7605871	70.52774	-1.035051
64.0141	6.0424385	73.46378	-0.669016
67.00088	5.3513126	76.17794	-0.397152
69.8449	4.6929415	78.62636	-0.216182
72.52122	4.0689629	80.77034	-0.113823
75.0049	3.4818334	82.57376	-0.072061
77.27444	2.9331908	84.00738	-0.069604
79.31006	2.423035	85.0497	-0.063872
81.09542	1.9513662	85.73512	-0.02866
82.61676	1.5206408		
83.86032	1.1275834		
84.81664	0.7795638		
85.46766	0.4618424		
85.85724	0.1555852		

Chord = 86 in $t/c = .219$ V22 Airfoils Scaled



3H248

Figure A-1. Comparison of 23% and 21.9% airfoil geometry.

REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, D.C. 20503

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
April 1993

3. REPORT TYPE AND DATES COVERED
Contractor Report

4. TITLE AND SUBTITLE

Civil Tiltrotor Transport Point Design - Model 940A

5. FUNDING NUMBERS

C NAS1-18796

6. AUTHORS

Charles Rogers, Dale Reisdorfer

WU 532-06-37-03

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Bell Helicopter Textron Inc.
P.O. Box 482
Fort Worth, Texas 76101

8. PERFORMING ORGANIZATION
REPORT NUMBER

699-099-352

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Langley Research Center
Hampton, VA 23681-0001 and
U.S. Army Aviation Systems Command St. Louis, MO 63166

10. SPONSORING / MONITORING
AGENCY REPORT NUMBER

NASA CR-191446

11. SUPPLEMENTARY NOTES

Langley Technical Monitor: D.J. Baker
Final Report - Task 6

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Unclassified - Unlimited

Subject Category 24

12b. DISTRIBUTION CODE

13.. ABSTRACT (Maximum 200 words)

The objective of this effort was to generate a point design 40 passenger civil tiltrotor transport using state-of-the-art composites technology from which structural optimization studies could proceed. Performance parameters include a range of 600 miles at a cruise speed of 375 knots. This report presents specific data on geometry, systems weight and loads. An initial structural sizing is included for the wing and center fuselage. Very simple guide lines are presented for determination of wing stiffness to avoid tiltrotor dynamic instability. This point design is a reasonable basis for initiating a structural optimization process.

14. SUBJECT TERMS

15. NUMBER OF PAGES
91

16. PRICE CODE

17. SECURITY CLASSIFICATION
OF REPORT

UNCLASSIFIED

18. SECURITY CLASSIFICATION
OF THIS PAGE

UNCLASSIFIED

19. SECURITY CLASSIFICATION
OF ABSTRACT

UNCLASSIFIED

20. LIMITATION OF ABSTRACT